(*Boechera pusilla*) Fremont County Rockcress Species Status Assessment

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Photo by Bonnie Heidel, WYNDD

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Executive Summary

This report summarizes the results of a species status assessment (SSA) completed for *Boechera pusilla* (Fremont County rockcress or small rockcress); hereafter Fremont County rockcress, to assess the species' overall viability. To assess the species' viability, we, the U.S. Fish and Wildlife Service (Service), used the three conservation biology principles of resiliency, redundancy, and representation (together, the 3Rs). Specifically, we identified the species' ecological requirements for survival and reproduction at the individual, population, and species levels, and described the factors, both positive and negative, influencing Fremont County rockcress viability. We evaluated the species' current levels of resiliency, redundancy, and representation, and forecasted changes into the future.

Fremont County rockcress is a narrow endemic perennial herb known to occur only in the southern foothills of the Wind River Range in Wyoming on land administered by the Rock Springs Field Office of the Bureau of Land Management. The species is found on approximately 7.3 hectares (18 acres) of habitat in a single location. The species is found in sparsely-vegetated, course, granite soil pockets in exposed granite-pegmatite (pegmatite is a very coarse-grained igneous (solidified from lava or magma) rock) outcrops. This area faces extreme cold temperatures, and strong, frequent winds, with only 30 frost-free days per year. Individual plants need sunlight, a patch of soil within the granite-pegmatite outcrops, precipitation during key periods of their life cycle, and freedom from competition. A key characteristic of this species is its apomictic reproductive system, in which individual plants reproduce through asexual seed production (see glossary for more complete definition). This means that our standard understanding of a "population" as a group of interbreeding individuals does not apply to this species. Therefore, the concepts of individuals and population are inextricably entwined, and we must consider both when evaluating the 3Rs for this species.

Not much is known about the historical condition of the species, since Fremont County rockcress was first discovered in 1981. It is presumed that the species has never been widespread, or occurred much outside its current distribution, due to its habitat restriction within granite-pegmatite outcrops. When the original occurrence was first counted in 1988, there were over 800 reproductive individuals in the entire occupied area, and over 600 flowering, reproductive individuals in the monitoring plot, a peak number that has not been achieved since that time. Therefore, an unknown factor was thought to be causing a decline in the abundance of the species, and it was petitioned for listing, and found to be warranted.

In this SSA Report, we evaluated the current condition of the species, as informed by past and present circumstances, and based on the 3Rs. To assess resiliency, we reviewed the abundance of flowering and non-flowering individuals and colonization of populations, which is driven by the species' apomictic reproductive system, winter precipitation, soil availability, sunlight, and freedom from competition. Stochastic events such as severe precipitation events, wildfire, and invasions of non-native invasive species affect the resiliency of the species. Presently, it appears that no stressors are affecting the species in a negative way, which is likely due to the conservation actions implemented by the Bureau of Land Management, which manages the land on which the species occurs, and by the protections afforded by the Secretarial Public Land Order 7312.

To assess redundancy, we evaluated the contribution of the single known occurrence, and considered the implications of the apomictic reproductive system to further contribute to the ability to withstand catastrophic events. The single occurrence could potentially be affected by catastrophic events, such as increased drought due to climate change, mineral development, wildfire, or sudden, intense, and long-lasting competition with invasive species.

To assess adaptive capacity (representation) in the absence of information on genetic diversity, we evaluated factors that could indirectly represent genetic variability within the species. These included morphological variability, phenological variability, habitat variability, the contribution of the single occurrence, and the apomictic reproductive system of this species, where each individual is capable of producing offspring like itself. Each of these factors contributes to the overall adaptive capacity of the species.

The current condition of the species is characterized by a single occurrence that is highly resilient, and the species has low to moderate levels of redundancy and low levels of representation. Overall, however, the species' current viability is characterized by persistence on the landscape as a narrow endemic with an apomictic reproductive breeding system, lack of stressors affecting the species, and protections in place to benefit the species.

To assess the potential future status of the species in the face of uncertainty on what the future conditions may be, we devised risk scenarios by evaluating information on six stressors: recreation, mineral extraction, nonnative invasive plants, predation, small population dynamics, and climate change. We developed three plausible future risk scenarios:

1) Continuation –the current trajectory and trends of the above-listed stressors continues into the future,
2) Best case – current conditions remain static, and
3) Worst-case – all above-listed stressors affect the species at levels worse than the current condition.

Based on these future scenarios, we predict that the future condition of the species could range from high levels of the 3Rs to low levels of the 3Rs, depending on analysis at the individual or population level, which scenario is used, and whether conservation actions are implemented. For example, in the best case scenario, we anticipate that the species overall would have moderate to high condition, coupled with a lack of threats affecting the species. On the other hand, in the worst case scenario, the species would suffer the effects of climate change and competition and have moderate to low condition. In general, into the future, the species is characterized by the stability of the current occurrence, lack of stressors affecting the species, and regulatory protections in place.

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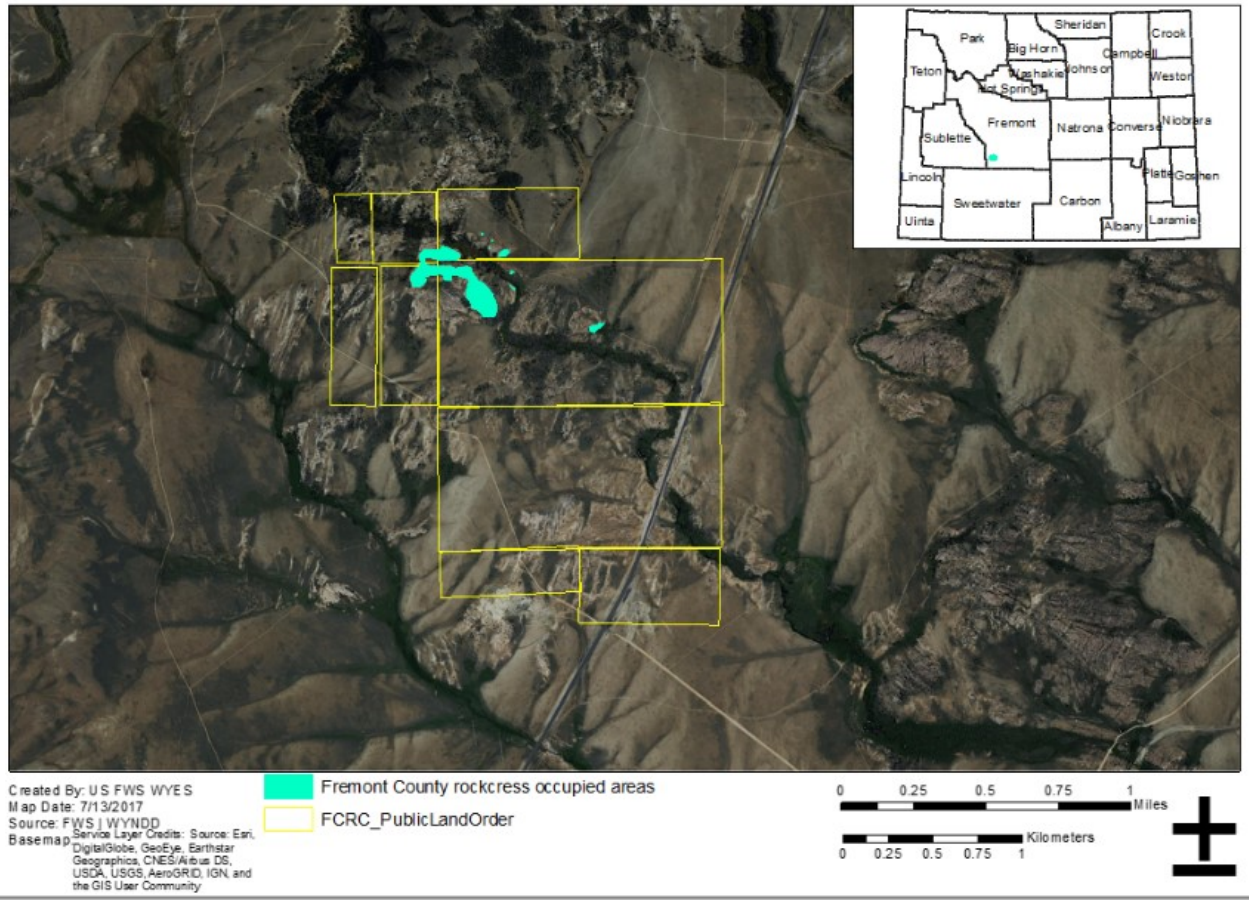
Chapter 1. Introduction, Data, and Analytical Framework

This report summarizes the results of a SSA analysis conducted for *Boechera pusilla* (Fremont County rockcress or small rockcress; henceforth, we use the common name Fremont County rockcress). Fremont County rockcress is a narrow endemic herbaceous perennial plant found only in the South Pass area south of the Wind River Range in Fremont County, Wyoming (see Figure 1). This species is only known from a single occurrence that occurs entirely on lands administered by the Rock Springs Field Office of the Bureau of Land Management (BLM). It is currently a Federal candidate species for listing under the Endangered Species Act (Act), and as part of our National Listing Workplan, the U.S. Fish and Wildlife Service (Service) must determine whether it should be listed under the Act by Fiscal Year 2018.

Figure 1. Range of Fremont County rockcress and the boundaries of Public Land Order (PLO) 7312.



Using the SSA Framework (USFWS 2016, entire), this SSA Report provides an in-depth review of the species' biology and stressors, an evaluation of its biological status, and an assessment of the resources and conditions needed to maintain long-term viability. The intent is for the SSA Report to be easily updated as new information becomes available and to support all functions of the Endangered Species Program from Candidate Assessment to Listing to Consultations to Recovery. As such, the SSA Report will be a living document upon which other documents,

such as listing rules, recovery plans, and 5-year reviews, would be based if the species warrants listing under the Act.

This SSA Report for the Fremont County rockcress is intended to provide the biological support for the decision on whether to propose to list the species as threatened or endangered and, if so, whether to and where to propose designating critical habitat. Importantly, the SSA Report does not result in a decision by the Service on whether this taxon should be proposed for listing as a threatened or endangered species under the Act. Instead, this SSA Report provides a review of the available information strictly related to the biological status of the Fremont County rockcress. The listing decision will be made by the Service after reviewing this report and all relevant laws, regulations, and policies, and the results of a proposed decision will be announced in the Federal Register, with appropriate opportunities for public input, should public input be necessary under the Administrative Procedures Act (5 U.S.C. Subchapter II; Pub.L. 79-404, 60 Stat. 237; June 11, 1946, as amended).

1.1 Regulatory History

The Service the added Fremont County rockcress to the list of candidates for listing under the Act prior to 1987, and removed it from the candidate list in 2001 due to stable numbers of plants and the implementation of protections by the BLM and a Secretarial Public Land Order protecting the species' habitat (63 FR 9012; February 23, 1998). In 2007, the Service was again petitioned by Forest Guardians (now WildEarth Guardians) to list the species as part of a petition to list 206 species, and we determined the species was warranted but precluded for listing under the Act, and designated it as a candidate in 2011 based on survey information indicating the species was in decline. We have reevaluated the species' status annually since that time through the Candidate Notice of Review (CNOR) process. In the 2016 CNOR, we found that the threats affecting the species were no longer high in magnitude or imminent, and were instead low in magnitude and non-imminent, and therefore revised the listing priority number from an 8 to an 11 (81 FR 87246; December 2, 2016).

1.2 Analytical Framework

The SSA assesses the ability of Fremont County rockcress to maintain viability over time. To assess Fremont County rockcress viability, we used the three conservation biology principles of resiliency, redundancy, and representation, or the "3Rs" (USFWS 2016, entire). These principles are generally described later in this chapter, and more specifically for Fremont County rockcress in **Chapter 2**. Our approach for assessing Fremont County rockcress viability involved three stages. First, we described the species' ecology in terms of the 3Rs. Specifically, we identified the ecological requirements for survival and reproduction at the individual, population, and species levels, and this is described in detail in **Chapter 2**. Second, we determined the baseline condition of the species using its ecological requirements in **Chapter 3**. That is, we assessed the species' current condition in relation to the 3Rs, and identified past and ongoing factors (stressors and conservation actions) that led to the species' current condition. Third, using the current conditions along with the predictions for future factors, both positive and negative, that may influence the species from **Chapter 3**, we projected the likely future condition of Fremont County rockcress in **Chapter 4**. Finally, in **Chapter 5** we described the viability of Fremont County rockcress over time through a synthesis of current (influenced by past and ongoing factors) and future conditions analyses.

Viability is the ability to sustain populations over time. Therefore, a species must have a sufficient number and distribution of healthy populations to withstand changes in its biological (e.g., novel diseases, predators) and physical (e.g., climate) environment, environmental stochasticity (e.g., wet or dry, warm or cold years), and catastrophes (e.g., severe and prolonged droughts). Viability is not a single state—viable or not viable; rather, there are degrees of viability: less to more viable or low to high viability. Generally speaking, the more resiliency, redundancy, and representation a species has, the more protected it is against changes in the environment, the more it can tolerate stressors (one or more factors that may be acting on the species or its habitat, causing a negative effect), the better able it is to adapt to future changes, and thus, the more viable it is. The 3Rs framework (assessing the health, number, and distribution of Fremont County rockcress populations relative to the frequency and magnitude of environmental stochasticity and catastrophic events across its historical range of adaptive diversity) is useful for describing a species' degree of viability through time.

1.2.1 Resiliency

Resiliency is the ability to sustain populations in the face of environmental variation and stochastic events. Environmental variation includes normal year-to-year variation in rainfall and temperatures, as well as unseasonal weather events. Stochastic events may include fire, flooding, and storms. Simply stated, resiliency is having the means to recover from "bad years" and disturbances. To be resilient, a species must have healthy populations; that is, populations that are able to sustain themselves through good and bad years. The healthier the populations and the greater number of healthy populations, the more resiliency a species possesses. For many species, resiliency is also affected by the degree of connectivity among populations. Connectivity among populations increases the genetic health of individuals (heterozygosity) within a population and bolsters a population's ability to recover from disturbances via rescue effect (immigration). However, for Fremont County rockcress, since there is no evidence of sexual outcrossing, connectivity is difficult to detect and quantify. Furthermore, connectivity may not be a meaningful metric for genetic health of individuals in Fremont County rockcress, and so instead we described the apomictic reproductive system as providing a mechanism for individuals to express their genotype/phenotype and the advantageous adaptations that they provide.

1.2.2 Redundancy

Redundancy is the ability of a species to withstand catastrophic events. Redundancy protects species against the unpredictable and highly consequential events for which adaptation is unlikely. In short, it is about spreading the risk. In general, redundancy is measured at the species level, and is best achieved by having multiple populations widely distributed across the species' range. Having multiple populations reduces the likelihood that all populations would be affected simultaneously, while having widely distributed populations reduces the likelihood of populations possessing similar vulnerabilities to a catastrophic event. Given sufficient redundancy, single or multiple catastrophic events are unlikely to cause the extinction of a species. Thus, the greater redundancy a species has, the more viable it will be. For most species, the more populations and the more diverse or widespread that these populations are, the more likely it is that the ability to withstand catastrophic events will be preserved. Having multiple populations distributed across the range of the species will help preserve the breadth of adaptive

diversity, and hence, the evolutionary flexibility of the species. However, for Fremont County rockcress, it is also possible to assess redundancy at a much smaller scale, and even within the population level due to the apomictic reproductive system of this species and due to the scale of the habitat in which it occurs. While the suboccurrences within the single known occurrence provide some limited breadth of redundancy and protection from catastrophic events due to their proximity to each other, it is possible that even low numbers of surviving individual of Fremont County rockcress may be capable of reproducing and repopulating an occurrence after a catastrophic event.

1.2.3 Representation

Representation is the ability of a species to adapt to near and long-term changes in the environment; it's the evolutionary capacity or flexibility of a species. Representation, as measured at the species level, is the range of variation found in a species, and this variation--called adaptive diversity--is the source of species' adaptive capabilities. Representation can, therefore, be measured through the breadth of adaptive diversity of the species. The greater the adaptive diversity, the more responsive and adaptable the species will be over time, and thus, the more viable the species is.

Maintaining adaptive diversity includes conserving both the ecological diversity and genetic diversity of a species. By maintaining these two sources of adaptive diversity across a species' range, the responsiveness and adaptability of a species over time is preserved. Ecological diversity is the physiological, ecological, and behavioral variation exhibited by a species across its range. Genetic diversity is the number and frequency of unique alleles within and among populations. For Fremont County rockcress, we do not have genetic information to tell individuals apart, and because of the apomictic reproductive system, and assuming that the founders of the species arose from a single hybridization event, it is likely that most individuals within the species are genetically quite similar to each other. Furthermore, without information on heritable genetic variation for this species, we focus our assessment instead on phenotypic variation. In asexually-reproducing species, such as Fremont County rockcress, natural selection applies more weakly than it does in sexually-reproducing species due to a lack of recombination. Therefore, we focused our analysis of representation on morphological, phenological, and ecological variability, partnered with consideration of the one occurrence and the suboccurrences, and the species' apomictic reproductive system.

Chapter 2. Species Ecology and Needs

In this chapter, we briefly describe Fremont County rockcress taxonomy and discuss the species' life history characteristics at the individual, population, and species levels. This is not an exhaustive review of the species natural history; rather, it provides the information relevant to understanding the ecological basis for the SSA analyses conducted in **Chapters 3-5**.

2.1 Species Taxonomy and Description

Fremont County rockcress is a member of the Brassicaceae (mustard) family that was published under the name *Arabis pusilla* after its discovery in 1981 (Rollins 1982, entire). The current

name of the species is *Boechera pusilla* (Al-Shehbaz and Windham 2010). Löve and Löve (1976) first suggested recognizing *Boechera* as a genus distinct from *Arabis* based on different base chromosome numbers (n=7 in *Boechera*, n=8 in *Arabis*). Al-Shehbaz (2003) noted that this difference in chromosome numbers is also supported by phylogenetic studies indicating these species are more closely related to other genera, including *Halimolobos*, *Sphaerocardamum*, and *Crucihimalaya*, than to other members of the genus *Arabis*, and by morphological distinctions between the two genera. Al-Shehbaz consequently transferred most North American members of *Arabis* to *Boechera* (Al-Shehbaz 2003, entire). The phylogenetic results have been further supported by later research (e.g., Bailey *et al*. 2006) and the transfer of these species to *Boechera* has been widely accepted (Holmgren *et al*. 2005, p. 537; Al-Shehbaz and Windham 2010).

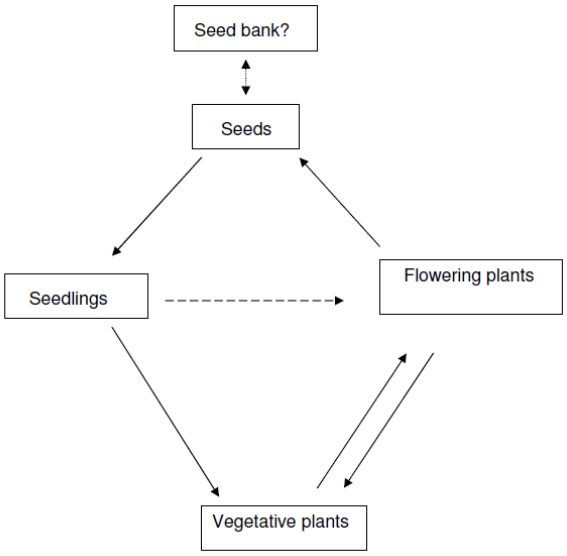
For the purpose of this SSA assessment, we consider *Boechera pusilla* to be the scientific name of this species, with *Arabis pusilla* as a synonym, and follow the nomenclature of Al-Shehbaz and Windham (Flora of North America (FNA); 2010) for other species of *Boechera*. Rollins (1982, p. 108) compared it to *Arabis demissa* var. *languida* (nodding rockcress; now *Boechera languida*), *Arabis pendulina* var. *russeola* (Daggett rockcress; *Boechera "wyomingensis"* as discussed by Alexander et al. 2015), and *Arabis oxylobula* (Glenwood Springs rockcress; now *Boechera oxylobula*). Although the latter is a western Colorado endemic, the other two are widespread in western Wyoming with *B."wyomingensis"* occurring in close proximity to the Fremont County rockcress (Dorn 1990, p. 5; Heidel 2005, p. 2). Various hybrid origins have been proposed for the Fremont County rockcress, including *B. pendulina* (rabbit-ear rockcress) x *B. lemmonii* (Al-Shehbaz 2010, p. 400) or *B. pendulocarpa* x *B. microphylla* (Marriott 2016, p. 1). More recent genetic analyses have indicated that rabbit-ear rockcress appears to include several unpublished cryptic species, one of which is provisionally called *Boechera* "*wyomingensis*" (Wyoming rockcress), and that Fremont County rockcress is an apomictic triploid hybrid between Lemmon's rockcress, Glenwood Springs rockcress, and Wyoming rockcress (Windham 2016, pers. comm.). Hybridization is common in *Boechera*, with hybrids forming reproductively independent and genetically distinct lineages that do not interbreed with each other or introgress (transfer genes back and forth) with their parents (Windham and Al-Shehbaz 2006; Beck *et al*. 2012; Alexander *et al*. 2015). The only functional pollen produced by the species indicates that it is an apomictic triploid (Windham 2016, pers. com.) and its occurrence in a highly-specialized habitat that is newly formed suggests that the species is relatively recently derived (Dorn 1990, p. 5). Consequently, we regard Fremont County rockcress as a valid hybrid (allopolyploid) species as *Boechera lemmonii* × *oxylobula* × *pendulina* (using the FNA nomenclature) or *Boechera lemmonii* × *oxylobula* × "*wyomingensis*" (using Windham's provisional nomenclature).

Fremont County rockcress is a short-lived perennial herb with a simple, mostly nonbranching caudex (persistent, swollen stem base); few slender, weak, slightly decumbent (lying down) 6-12 centimeter (cm) (2.36-4.72 inch (in.)) long stems; erect linear to linear-oblanceolate (pointed at end of base) basal leaves 1-1.5 cm (0.39-0.59 in.) long; 4-8 mm (millimeter) (0.16-0.31 in.) long cauline (stem) leaves; light lavender 3.5-4.5 mm (0.14-0.18 in.) long spatulate (broad at the apex and tapered to the base) petals; and widely-spreading 1-1.5 cm (0.39-0.59 in.) long and about 2 mm (0.08 in.) wide, silique (long, narrow dehiscent) fruits (Rollins 1982, p. 194; Marriott 1986, p. 3; Al-Shehbaz 2010, p. 400). Plants flower during the short growing season in May and June with fruits maturing several weeks later (Marriott 1986, p. 12; Fertig 1994, unpaginated; Heidel 2005, pp. 3, 15).

The life cycle for Fremont County rockcress is presented in Figure 2 based on what is known about the species. Reproduction of Fremont County rockcress is by (nonwinged) seeds that likely drop near the parent plant, with some seeds likely dispersed via wind or water (Dorn 1990, p. 9). Other potential dispersal vectors are unknown at this time (Heidel 2005, p. 15), though it is likely that the persistent and strong winds present within Fremont County rockcress habitat is sufficient to disperse the species' seeds. Seeds appear to germinate in the fall, and plants tend to remain vegetative in the first growing season, meaning they do not flower, and then in the second growing season, they flower. However, there are exceptions where first year plants may flower and plants may remain vegetative for multiple consecutive years. No population demographic studies have been conducted on this species to date. We are unsure if Fremont County rockcress forms a seedbank due to the lack of soil accumulation in its habitat. Plants appear to be more likely to produce flowering stalks in wet years and are less likely to produce flowering stalks in dry years, and plants have been observed to move back and forth between a flowering and vegetative state between years, or can be vegetative or flowering for more than one year in succession. We are uncertain on the lifespan this species (Heidel 2012, p. 12).

Not all plants produce fruit in a particular year (Heidel 2005, pp. 15–16). We do not have information about how long the species' seeds remain viable, or under what conditions they germinate. The species has relatively few seeds per fruit compared to some other *Boechera* species (Dorn 1990, p. 9). Some life history information is currently unknown, including information on plant growth stages, longevity, the length of time it takes to flower, and whether or not an individual plant can flower multiple times.

Figure 2. Life cycle of Fremont County rockcress. Like most plants, seeds become seedlings, which are then vegetative plants, and then flowering plants. Adult plants can move from vegetative to flowering and back in a given year. The dotted line between seedlings and flowering plants represents the presumed rare transition between a seedling and flowering plant in one year. (Taken from Heidel 2012, Figure 10, p. 13).



2.2 Habitat Description

Found only near South Pass City south of the Wind River Range in Fremont County, Wyoming (see Figure 1.), Fremont County rockcress occupies sparsely vegetated, coarse granite soil pockets in exposed granite-pegmatite outcrops, with slopes generally less than 10 degrees, at an elevation between 2,438 to 2,469 meters (m) (8,000 to 8,100 feet (ft)) (Dorn 1990, pp. 3, 6). A pegmatite is a very coarse-grained igneous (formed from magma or lava) rock that usually occurs in dikes (sheet-like bodies of magma) (Heidel 2005, p. 8). The soils are sandy to loamy (mixture of clay, silt and sand), poorly developed, very shallow, and possibly subirrigated by runoff from the adjacent exposed bedrock (solid consolidated rock) (Dorn 1990, pp. 6–8). Fremont County rockcress is likely restricted in distribution by the limited occurrence of pegmatite in the area (Heidel 2005, p. 8), though there is possibility that the species may be more far-ranging based on the distribution of its parent species and the concept of geographical parthenogenesis (where apomictic species have wider distributions than their sexual relatives; Hörandl 2009 p. 161). The single known occurrence lies on approximately 7.2 hectares (ha) (18 acres (ac)) of habitat. A distribution model shows that potential habitat could occur across an area no greater than two townships (186.5 square kilometers (km^2); 72 square miles (mi^2)) (Heidel 2005, p. 7), and a more recent model predicts that this species will be found nowhere else in the state (Andersen *et al*. 2016, Appendix 2, pp. 151–154), though there is potential for additional occurrences in nearby areas that have not been surveyed. However, much of the surrounding area that is administered by the Rock Springs Field Office of the BLM has been surveyed for this species and no other occurrences have been found to date. In 2016 and 2017, a new occurrence and an expansion of the first occurrence were thought to be discovered, respectively; however, these plants were determined to be a different species than Fremont County rockcress. The dense nature of pegmatite combined with the persistent, strong winds, does not allow for fertile soil formation, therefore restricts vegetation growth (Heidel 2005, p. 15). The specialized habitat requirements of Fremont County rockcress have allowed the plant to persist without competition from other herbaceous plants or sagebrush-grassland species that are present in the surrounding landscape (Dorn 1990, pp. 6, 8), though no specific studies have been conducted to determine the exact values of these specialized habitat parameters.

Although the surrounding vegetation is sparse (less than 10 percent cover), Fremont County rockcress is associated with numerous mat-forming perennial herbs (e.g., *Erigeron caespitosus* (tufted fleabane)), perennial grasses (e.g., *Achnatherum hymenoides* (Indian ricegrass)), and shrubs (e.g., *Artemesia arbuscula* (dwarf sagebrush) and *Selaginella densa* (spikemoss)) (Heidel 2005, p. 9). Rolling hills are the predominant landscape features in the area, which is a transition zone between the montane conifer forests and the high sagebrush desert (Heidel 2005, pp. 8–9). The adjacent vegetation consists primarily of sagebrush-grassland or open *Pinus flexilis* (limber pine) habitat (Dorn 1990, p. 8).

Annual precipitation in the area is relatively low, and averages 30.5 cm (12 in.), with the majority falling in the form of winter snow (Marriott 1986, p. 9). Average minimum and maximum temperatures in this area range between -16.1 and -3.9 °C (3 and 25 °F) in January and between 4.6 and 24.4 °C (40 and 76 °F) in July (Dorn 1990, p. 6), with strong, frequent

winds present year-round (Heidel 2005, p. 10). This area has a very short growing season; approximately 30 frost-free days occur between mid-June and mid-July (Marriott 1986, p. 9). Fremont County rockcress may be adapted to wide fluctuations in available moisture as the limited soil layer goes through cycles of rapid drying and saturation (Dorn 1990, p. 6). The granite outcrops may be slow to warm in spring, but maintain heat later into the season. Additionally, the thin mantle of soil in and around outcrops shows patterns of frost heaving, which may or may not be something Fremont County rockcress is tolerant of, though it may help maintain sparse vegetation and lower competition conditions (Heidel 2012, p. 17).

2.3 Individual-level Ecology

Fremont County rockcress is an apomictic species, meaning it reproduces asexually and autonomously through agamospermy (seed production without fertilization). Apomixis is characterized by apomeiosis, where an egg cell is produced without being reduced during meiosis (two-stage cell division typical of sexually reproducing organisms that reduces chromosome number by half). This results in an egg cell with the same number of chromosomes as the mother plant. This egg cell undergoes parthenogenetic development (that is, without fertilization) to become an embryo that is genetically identical to the mother plant. Apomixis is a rather common reproductive system in plants, and apomicts tend to be perennial plants that are found in frequently disturbed habitats, those which were recently glaciated, or those with short growing seasons (Bicknell 2004, p. S229), as is the case with Fremont County rockcress. Additionally, autonomous, asexual reproductive systems are favored in unfavorable climates and those areas with unreliable pollinator service (Richards 2003, p. 1087). Indeed, no pollinator visitation has been documented during Fremont County rockcress monitoring (Heidel 2012, p. 12), which suggests that no or minimal pollen movement occurs between individual plants. Other triploid members of the *Boechera* genus have been found to be obligate apomicts (Aliyu *et al*. 2010, p. 1723). Cytogenetic analyses of Fremont County rockcress reveal a chromosome number of $n = 2n = 21$, indicating that it is an obligate apomictic triploid. In addition, most of the 15 microsatellite loci studied to date show three alleles, suggesting that the species is trigenomic (i.e., contains three genetically divergent genomes). Having three copies of each gene may provide some degree of genetic redundancy, which may improve the level of phenotypic plasticity the species exhibits, though we are uncertain of the level.

Regarding individual genetic variability, a microsatellite analysis of six individuals suggested that all sampled individuals derived from a single hybrid origin, and that genetic variability among the sampled individuals is confined only to two rapidly evolving loci (Windham 2016, pers. comm.). We understand that individuals may apomictically produce offspring that are not identical to the mother plant because some genetic recombination events may occur during chromosomal synapsis (pairing) during meiosis (Kantama 2007, p. 14029). Apomicts have a stage of reproduction composed of a single cell, similar to a zygote, in which the chance of mutation is increased (van Dijk *et al*. 2009, p. 49). Without recombination during meiosis, the genome of apomictic and other asexual species would become giant linkage groups (where all linked genes move as a unit rather than independently), which theoretically would accumulate recessive mutations (a principle known as ‘Muller’s Ratchet’; Felsenstein 1974). These accumulated recessive mutations would be expressed in diploid maternal lines through haploid products of reductional meiosis; that is, in typical meiosis, the four resulting daughter cells contain a haploid copy of one of the two mother chromosomes, which could include recessive

mutants. Because most agamospermic apomictic species are polyploid, these mutations are not expressed since the embryo is unreduced (Richards 2003, p. 1086). This is likely the case for Fremont County rockcress, and therefore individuals of the species are likely slow to be affected by deleterious alleles.

Furthermore, agamospermic apomictic species tend to have high heterozygosity (containing two (or more) different alleles of a given gene), which is likely derived from their hybrid origins (Richards 2003, p. 1087). Because daughter plants tend to maintain the identity and therefore heterozygosity of the mother plant, apomictic species tend to be fixed at the heterozygous state (though meiotic crossing over occurs in diplosporic species which can lead to some level of homozygosity at the distal regions of the chromosome) (van Dijk *et al*. 2009, p. 53). Being in this fixed heterozygous state suggests that hybrid apomicts are vigorous, and have the capability for phenotypic plasticity (Richards 2003, p. 1087), though this heterozygosity and plasticity play an unknown role in how the species effectively responds to stochastic events or to what level the species is specialized in its current ecological niche.

In summary, we understand that Fremont County rockcress is a triploid apomictic hybrid species likely of three *Boechera* species, two of which presently occur in the area. It reproduces only through apomixis, where seeds are formed without fertilization and therefore daughter plants are theoretically identical to the mother plant. All individuals within an occurrence, and possibly within the entire species, may be identical, or nearly so. However, due to its hybrid origin and triploid genome, Fremont County rockcress is likely highly heterozygous and therefore potentially exhibits high phenotypic plasticity, and may not suffer from deleterious effects of accumulated recessive mutations. Furthermore, polyploid hybrid vigor may improve Fremont County rockcress' ability to utilize habitats that are not suitable for other species or for one of the species' diploid progenitors (Fowler and Levin 1984, p. 703).

The life stages (see Figure 2) of Fremont County rockcress require very similar resources (see Table 1). At the seed stage, wind must dislodge seeds from the fruit of the mother plant, and the seeds must be deposited on soil that is derived from granite-pegmatite. To germinate, the seed needs an unknown amount of late summer or fall precipitation prior to the end of the growing season, soil derived from granite-pegmatite, and sunlight for an unknown number of hours per day. It has been hypothesized that the smallest single-rosette plants are young plants, though that has not been proven. Competition with other species and/or nonnative invasive species can restrict seedlings, vegetative plants, and flowering plants from obtaining the three key resources (water, soil, and sunlight) they need. Vegetative and flowering plants require the same key resources: soil derived from granite-pegmatite, some unknown amount of spring and summer precipitation, and sunlight. A summary of these resource needs is provided in Table 1. A highly resilient individual would be one that has all of its resource needs met.

Table 1. Individual resources needs by life stage. H = Habitat, N = Nutrition, R = Reproduction, D = Dispersal. Key resource needs are soil, precipitation, and freedom from competition.

Life stage	Resource and/or circumstances needed for individuals to complete life stage	Resource function (HNRD)
Seed	Fall/winter **precipitation**	N
	Soil derived from granite-pegmatite	H
	Wind to dislodge seeds from silique	D
Seedling	Sufficient summer/fall **precipitation**	N
	Soil derived from granite-pegmatite	H
	Freedom from competition with invasives/encroaching plants	H, N
	Sunlight for photosynthesis	N
Vegetative plant	Spring/summer **precipitation**	N
	Soil derived from granite-pegmatite	H
	Freedom from competition with invasives/encroaching plants	H, N
	Sunlight for photosynthesis	N
Flowering plant	Spring/summer **precipitation**	N
	Soil derived from granite-pegmatite	H
	Freedom from competition with invasives/encroaching plants	H, N
	No pollinators required	R
	Sunlight for photosynthesis	N
Resource needs taken from Marriott 1986, entire and Dorn 1990, entire		

2.4 Population-level Ecology

In most species, populations are defined by genetic exchange among individuals. However, in apomictic species, which do not have genetic exchange, it is difficult to define populations. It has been suggested that populations of apomictic species can be defined in one of three ways: (1) a population is restricted to plants in recent genetic contact, (2) a population includes all coexisting members of a genus, or (3) a population is composed of members of the same "agamospecies" from the same locality (Richards 2003, p. 1087, Majesky et al. 2015, p. 2105). All of these published options prove to be problematic in defining populations for Fremont County rockcress. The first option does not define how recent the genetic contact needs to be in order for a group of individuals to be considered a population, and for the Fremont County rockcress, we do not have information on how recently the species evolved. The second option lacks justification for combining individuals at the genus level, does not define how close together individuals must be to be considered "coexisting," and for the Fremont County rockcress, would potentially include other diploid *Boechera* species occurring in the same habitat. The third option does not define "agamospecies" and critics think that agamospecies should be defined as having almost no genetic variation among individuals. For Fremont County rockcress, the third option is likely the closest approximation to a population, though we believe that there is potential for genetic variation among individuals through the movement of genes during the crossing-over period within meiosis.

Due to the aforementioned complexities, in this analysis we will define groups of individuals of Fremont County rockcress within close physical proximity (i.e. within 0.5 kilometers (km) (0.31 miles (mi)) to one another and separated from each other by more than 1 km (0.62 mi) of unsuitable habitat to comprise an "occurrence," and we use this definition of occurrence as our unit of analysis for this SSA Report. We use the term "occurrence" to roughly mean "population," though for this species it does not imply genetic exchange or connectivity. Based on this definition, there is a single known occurrence. This occurrence (hereafter Occurrence 1) is composed of eight distinct areas containing plants, referred to here as "suboccurrences," which are arbitrary groupings based on the survey methodology used by Wyoming Natural Diversity Database (WYNDD). These suboccurrence boundaries are a somewhat artificial construct to aid in monitoring and are not necessarily biologically relevant. A second occurrence was believed to be discovered in 2016, and an extension of Occurrence 1 was believed to be discovered in 2017, though these were later determined to be a different species of *Boechera*.

Population-level needs are an accumulation of the resource needs of individuals (see Table 1 under **Section 2.2 Individual-level Ecology**). Each individual plant reproduces autonomously and asexually, and reproduction likely only occurs when the appropriate individual-level resource needs (*i.e.* soil, water, sunlight, and freedom from competition) are met. In addition to the individual-level needs, a further population-level need is that some undetermined number of individuals needs to germinate and survive to replace individuals that have died. For most species, we assess population-level resilience based on the number of individuals (*i.e.*, abundance), colonization, recruitment, connectivity, and population growth. However, because the Fremont County rockcress is apomictic and does not interbreed, the concept of connectivity is not a valid measure of population health or resilience. Additionally, because seedlings have never been counted as part of routine monitoring, we have no information on the recruitment rate for this species, though we understand that new recruits compose a portion of the number of non-flowering, vegetative plants in any year. Abundance of flowering and non-flowering plants and colonization are demographic factors that contribute to the resiliency of the Fremont County rockcress occurrence and can be quantified in a meaningful way. For example, we assume that the higher number of flowering and non-flowering individuals in an occurrence and the more areas of occupied suitable habitat, the higher the resilience of that occurrence would be in the face of stochastic events. Based on other *Boechera* species' demographic constraints and evolutionary history, a viable population for the Fremont County rockcress may be 500 to 5,000 plants (Ladyman 2005, p. 26), though no population viability analysis has been conducted on Fremont County rockcress to know an exact value for a viable population.

2.5 Species-level Ecology

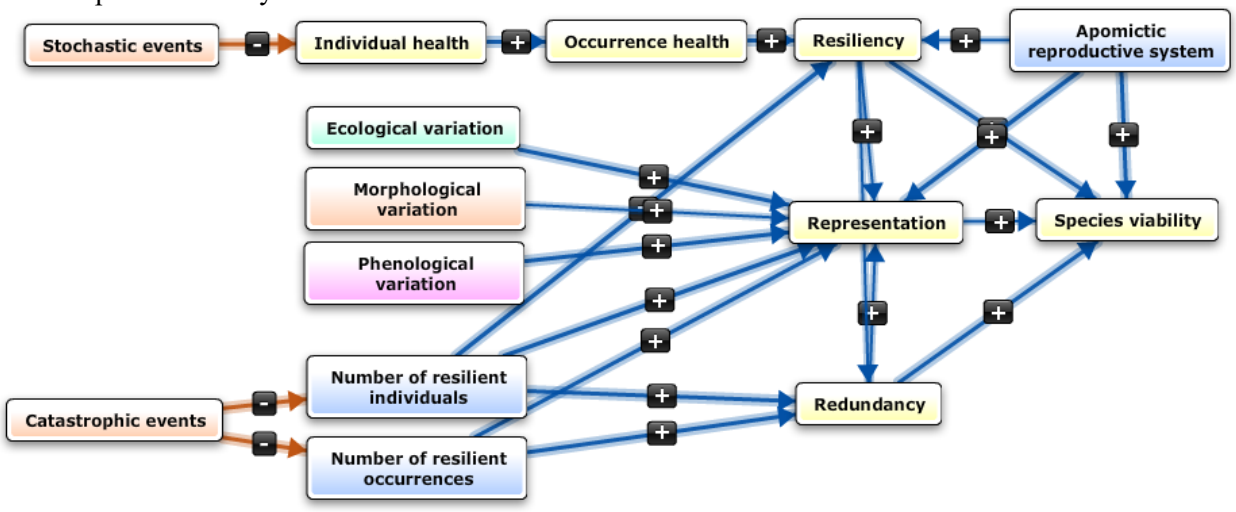
In this section, we describe the ecological requirements at the species level in terms of the 3Rs. First, we define and clarify what we mean by the term "species" for the Fremont County rockcress. As discussed earlier under **Section 2.2 Individual-level Ecology**, many species in the genus *Boechera* contain both diploid sexually reproducing individuals and polyploid apomicts. However, because Fremont County rockcress is a hybrid of two other nearby species in the genus *Boechera* (Al-Shehbaz 2010, p. 400; Marriott 2016, p. 1), we assume that the species is composed entirely of polyploid apomicts. At times, individuals of an apomictic species have been described as "microspecies," as in *Taraxacum* (dandelions; van Dijk *et al*. 2009, p. 479); or "agamospecies," as in *Hieracium* subg. *Pilosella* (hawkweeds), *Ranunculus auricomus*

(buttercups), and *Rubus fruticosus* (blackberries; Horandl 2009, p. 162) based on the differences among individuals either by ploidy level (number of sets of chromosomes), morphology, and/or ecological features. Because of the apomictic reproductive system of this species, the Fremont County rockcress as a species is defined as all individuals with the same genetic lineage, that is, the offspring and their progeny of the same hybridization event or events.

Species-level needs are probably very similar to the resource needs at the individual level (see Table 1 under **Section 2.2 Individual-level Ecology**). Viability is a measure of the ability to sustain populations over time. To have high viability, Fremont County rockcress needs a sufficient number and distribution of populations to withstand environmental stochasticity (resiliency), catastrophes (redundancy), and changes in its environment (representation) (see Figure 3).

In Figure 3, we depict that the species needs a combination of highly resilient populations that are composed of highly resilient individuals, meaning that populations would have some ability to withstand stochastic events. For the Fremont County rockcress to maintain high levels of redundancy, it needs a sufficient number of highly resilient individuals composing highly resilient populations to protect against catastrophic events. For the species to maintain high levels of representation, it needs sufficient distinct variation in terms of occurrences, ecological settings, morphology, and phenology. However, we lack the information to quantify what levels of these factors are necessary for this species to maintain high levels of viability. The apomictic reproductive system of Fremont County rockcress contributes to the overall level of viability of the species through the additive resilience of individual plants (see **Section 2.2 Individual-level Ecology**).

Figure 3. Species viability conceptual model, which is composed of the 3Rs. Resiliency is determined by the health of individuals and occurrences, which are influenced by stochastic events. Representation is determined by the types of ecological, morphological, phenological, and occurrence variation. Redundancy is determined by the number of resilient occurrences, which are influenced by catastrophic events. The apomictic reproductive system of this species has the potential to influence the 3Rs and overall species viability.



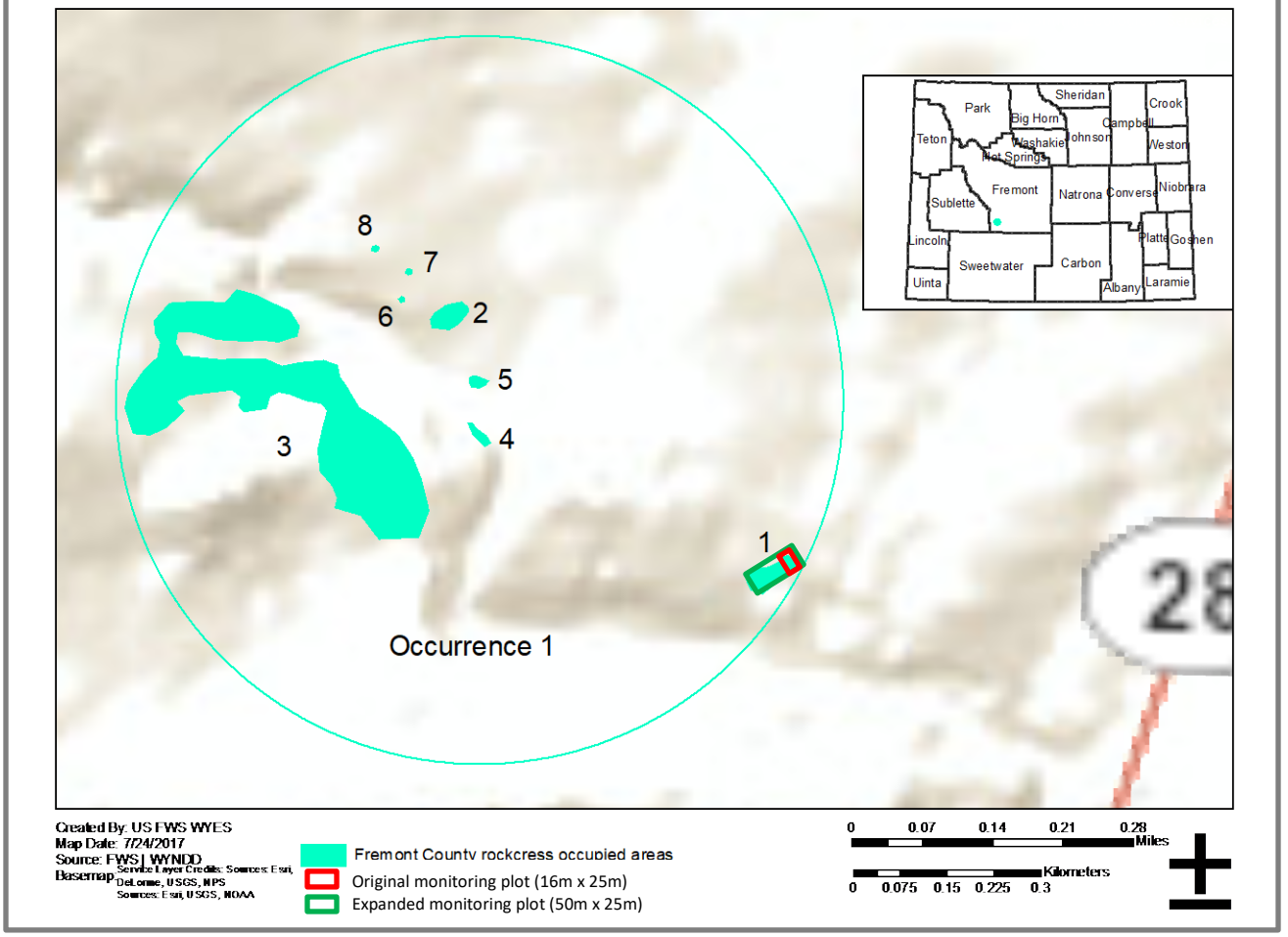
Chapter 3. Species Current Condition

In this chapter, we will review the historical and current trends in species numbers, explain assumptions about the main drivers affecting population trends, and assess the various stressors that may have influenced the species historically and currently.

3.1 Historical and Current Population Trends

The Fremont County rockcress was first discovered in 1981 (Rollins 1982, entire), and was found in a single location (Occurrence 1 in Figure 4). Only 50 plants were found in 1986; however, only one suboccurrence had been discovered at that time (likely suboccurrence 1; Marriott 1986, p. 15). Later surveys found a total of eight suboccurrences (Amidon 1993, entire). Most of the suboccurrences are small in size (ranging from 80.9 square meters (m^2) (0.02 ac) to 65,964 m^2 (16.3 ac)) and in number of individual plants (less than 10 plants to 925 plants (Heidel 2016b, p. 8)). Figure 4 provides a map of the eight suboccurrences in Occurrence 1. The occurrence data used for our analyses are primarily based on monitoring reports generated by The Nature Conservancy and WYNDD between 1986 and 2016.

Figure 4. Fremont County rockcress occurrence and suboccurrences. The suboccurrences in Occurrence 1 are numbered 1 through 8. The original and expanded monitoring plots are located in suboccurrence 1.



While the most comprehensive monitoring efforts occurred in 2003 (Heidel 2005, entire), 2011 (Heidel 2012, entire), and 2016 (Heidel 2016b, entire), no complete or exhaustive counts have been conducted for Fremont County rockcress in any year. Therefore, we use the estimates of total flowering plants in the most complete counts of the entire species, as well as the total flowering plants in a monitoring plot located in suboccurrence 1 that was considered to have the greatest numbers to explain the trends in Fremont County rockcress over time (see red outline of suboccurrence 1 in Figure 4). These two indicators are the most consistently documented information available. The number of flowering plants (rather than vegetative plants) is used, at least in part, to ensure identification of the species (Heidel 2016a, p. 2). However, any given plant may oscillate between flowering and nonflowering conditions from year to year, and the ratio between flowering and nonflowering plants differs between years. This difference may mask trends. Therefore, starting in 2003, researchers began monitoring nonflowering plants to provide context for flowering trends. Some of the years with lowest numbers of flowering plants have had relatively high proportions of nonflowering plants (Heidel 2016b, pp. 4–6). Therefore, the results of monitoring of flowering individuals do not provide a complete picture of true abundance within a suboccurrence. The number of non-flowering individuals can include both new recruits and adult non-reproductive individuals. When reviewing the abundance of flowering and non-flowering individuals over time, increases indicate that some level of recruitment is occurring.

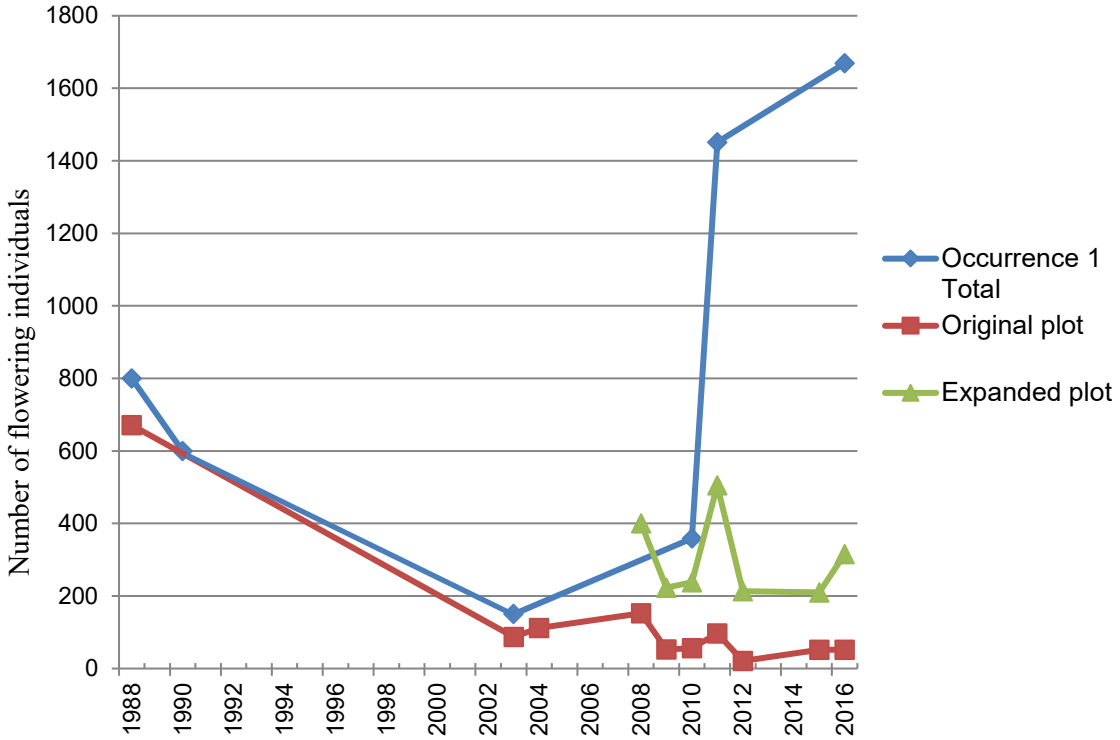
A replicated monitoring design in suboccurrence 1 was conducted for a total of ten years, starting in 1988, including consecutive annual monitoring for the five year period from 2008-2012 (Heidel 2005, p. 14; Heidel 2012, p. 4; Heidel 2014, p. 3; Heidel 2016a p. 2; Heidel 2016b, pp. 2–4). Monitoring was not conducted in 2005-2007, 2013, or 2014. This design involved taking a complete count of all plants within a specific 16 m by 25 m (52.5 ft by 82 ft) area totaling 400 m^2 (4305.5 ft^2) within suboccurrence 1, which appeared to contain almost all plants in the suboccurrence (Marriott and Horning 1988, p. 1). We refer to this monitoring area as the "original plot" (see red outline of suboccurrence 1 in Figure 4). Between 2008 and 2016, a larger, 25 m by 50 m (52.5 ft by 164 ft) area totaling 1250 m^2 (13454.9 ft^2) monitoring plot, referred to as the "expanded plot", was also monitored; this expanded plot encompasses the original plot (see green outline in suboccurrence 1 in Figure 4). The expanded plot was developed because it was determined that a significant number of additional plants were located within contiguous habitat outside the original monitoring plot (Heidel 2012, p. 2) and that the original monitoring plot no longer encompassed almost all of the plants within the suboccurrence. Therefore, the monitoring area was expanded to provide a more representative count of the number of plants within suboccurrence 1. A summary of monitoring effort and results for Occurrence 1 by year is provided in Table 2.

Table 2. Monitoring details for flowering Fremont County rockcress in Occurrence 1: total estimated number of flowering individuals, number of flowering individuals in the 400 m^2 (original) and 1250 m^2 (expanded) plots in suboccurrence 1. Note that monitoring vigor varied over years and so numbers are not directly comparable.

Year	Occurrence 1 total esimtate	400 m^2 "original" plot	1250 m^2 "expanded" plot	Monitoring Rigor
1986	50			Incomplete estimate
1988	800-1000	671		Complete count in original monitoring plot and robust estimate elsewhere
1990	600			Estimate that included at least the monitored suboccurrence area
2003	150-250	87		Complete count in the original monitoring plot and robust estimate elsewhere
2004		112		Complete count in original monitoring plot
2008		152	400	Complete count in original and expanded monitoring plot
2009		53	223	Complete count in original and expanded monitoring plot
2010	359	56	238	Complete count in original and expanded monitoring plot
2011	1451	97	505	Complete count in original and expanded monitoring plot and 3 largest suboccurrences
2012		21	213	Complete count in original and expanded monitoring plot
2015		52	210	Complete count in original and expanded monitoring plot
2016	1669	52	316	Complete count in original and expanded monitoring plot and 5 largest suboccurrences

In addition to monitoring the specific monitoring plots, researchers occasionally estimated the abundance of flowering plants in Occurrence 1 in 1988, 2003, 2010, 2011, 2015, and 2016 (Table 2 and Figure 5). In 1988, the total estimate was 800 to 1,000 flowering individuals (Heidel 2005, p. 14). Although the 1988 survey indicated no evidence that Fremont County rockcress was affected by the 1988 drought (Marriott and Horning 1988, p. B2), drought impacts (such as reduced seed fecundity or germination) may not be immediately apparent and may instead manifest in later years (Heidel 2012, p. 18).

Figure 5. Number of flowering individuals recorded in Occurrence 1 over time. Variation in counts of the entire occurrence (in blue), original plot (in red), and expanded plot (in green) indicate the species exhibits high variability in the number of flowering plants across years. Note that the Occurrence 1 Total in 1990 was an estimate and not a complete census, and that 1988 through 2010, 2012, and 2015 represent most of one suboccurrence but not all suboccurrences, and 2011 represents the three largest suboccurrences in Occurrence 1. Only 2016 provides a complete census of Occurrence 1.



In a separate and not comparable study, in 1990, numbers of flowering plants for the entire Occurrence 1 (Dorn 1990, p. 8) decreased, which may have been due to a pattern of short-term decline under drought conditions that occurred in the area between 1988 and 1990 (Heidel 2005, p. 14), though a differing survey design used in 1990 makes comparison between years difficult (Dorn 1990, entire). Occurrence 1 was not monitored in its entirety or in the original monitoring plot between 1988 and 2003. Declines in abundance of flowering plants perceived from 1988 to 2003 may be attributed to severe drought conditions recorded in the Wind River Range between 2000 and 2003 (NOAA 2005 as cited in Heidel 2005, p. 14). The 2011 survey included a more complete count of Occurrence 1, which included four out of the eight suboccurrences (the one suboccurrence repeatedly monitored in the original and expanded plots surveyed since 2008, and three additional suboccurrences) (Table 2). The apparent increase in abundance compared to previous years may be a reflection of that year's atypical, very moist spring and late growing season, and 2011 was the only monitoring year in which traces of snow were present. In addition, the scope of the count was expanded compared to previous years, so the high number of plants may not actually represent an increase in numbers. Occurrence 1 was counted again in 2016, which included five of the eight suboccurrences (the three remaining suboccurrences were not counted, but had fewer than 10 plants each at previous visits and were

presumed to have similar numbers in this year). Monitoring in 2016 estimated the abundance within Occurrence 1 to be 1,669 plants, which is higher than any previous abundance estimate to date (Table 2 and Figure 5). Because of the changing scope of the surveys, these abundance numbers do not necessarily indicate trends in abundance over time, though they do provide information on the presence of reproductive plants over time, which can be correlated with changes in the environment. Based on a limited number of surveys, Occurrence 1 appears to have an overall pattern of fluctuations centering on a potentially stable number.

Due to the variation in survey methods over time, it is difficult to develop conclusions on trends in abundance over time. However, since 1988, there have never been more than a quarter as many flowering plants in the original plot as there was in 1988, indicating decline. The original monitoring plot was installed to track trends in that portion of the suboccurrence over time, and subsequent monitoring in the original plot, the expanded plot, and in other suboccurrences has been conducted to obtain further context for the apparent decline. While a negative trend is discernable in the original plot, the expanded plot shows an increase in recent years (Heidel 2016b, pp. 3–4) (see Table 2 and Figure 5). This may be due to the natural dying off of some plants in one area and colonization of other plants in new areas, which was part of the rationale for the creation of the expanded plot in 2008. Furthermore, when including the number of non-flowering, vegetative and flowering individuals, both the original and expanded plot show increase in recent years (Heidel 2016b, pp. 4–5). This indicates that the species' abundance is not a simple count of flowering individuals in a monitoring plot but is more complicated and composed of all individuals within a larger area. Increases perceived in 2011 and 2016 in the total occurrence count correspond to more plants located in the expanded monitoring plot (Figure 5) as well as more areas being counted during the census.

There is a high likelihood that additional occurrences of this species may exist within the geographic area in unsurveyed areas. A potential distribution model for Fremont County rockcress was developed by WYNDD in 2005 based on bedrock geology, land cover, soil, surface geology, elevation, relief, precipitation, average air temperature, and shortwave radiation, which showed potential habitat occurring only within limited portions of two townships south of the Wind River Range in Fremont County, Wyoming (Heidel 2005, p. 7). A subsequent model found similar factors driving the location of the species (Andersen *et al*. 2016, Appendix 2, pp. 151–154). These areas on BLM land have been extensively surveyed without the discovery of a new occurrence since the species was first discovered. Without information about the species' extent within its potential range, we are limited in this SSA Report to analyzing the viability of the species based on the single known occurrence. However, if any new occurrences are found in the future, some of the assumptions of this SSA Report may no longer hold true.

3.2 Factors Affecting Current Condition

A number of factors, both positive and negative, may influence the species' current condition. Our 12-month finding (76 FR 33924; June 9, 2011) suggested that only a couple of the potential stressors named in the 2007 petition may impact the species. Here, we evaluate stressors that have the potential to impact the species, as well as conservation actions that may have an influence on the species' current condition.

3.2.1 Recreation

The habitat in which Fremont County rockcress occurs experiences some recreational use, due to the attraction of the riparian area nearby. Activities within the vicinity of Occurrence 1 associated with recreation include off road vehicle use associated with hunting, fishing, and camping, horse boarding and feeding, plant collecting, mountain biking, and pedestrian use. Conservation actions included in the BLM's Habitat Management Plan (BLM 1994, entire) included the installation of an exclosure fence in 1994, and the provision for ongoing maintenance of that fence to exclude vehicle access to Fremont County rockcress and its habitat. Repairs to the fence after a dead limber pine fell on it have effectively limited motorized access and any intense recreational use. Due to the implementation of those conservation actions, the only current access to the Fremont County rockcress and its habitat is to pedestrians, and this pressure is low (i.e. individual plants may be affected, but not the occurrence as a whole) because the majority of recreational traffic occurs along the riparian corridor outside of the site. Therefore, because we expect impacts from recreation to remain low through continued management of Fremont County rockcress habitat by BLM, we do not evaluate recreation further in our assessment of current condition or future scenarios. Our 12-month finding for Fremont County rockcress also found that this stressor was not impacting the species (76 FR 33924; June 9, 2011).

3.2.2 Energy Development and Resource Extraction

Energy development and resource extraction is a potential stressor to Fremont County rockcress. A currently inactive quarry may have destroyed potential habitat when it was created (Dorn 1990, p. 11; Heidel 2005, p. 17), and if natural gas development were to occur within the vicinity of Fremont County rockcress habitat, it could potentially impact the species (USGS 2010, p. 3). However, the area occupied by Occurrence 1 has been incorporated into a Special Recreation Management Area (SRMA), which is closed to mineral and energy development (BLM 1997, pp. 17–18). The nearest gas development occurs approximately 27 km (17 mi) from the location of Fremont County rockcress (Wyoming Oil and Gas Commission 2016), and does not appear to be impacting the plant.

Furthermore, on February 23, 1998, the Secretary of the Interior issued Public Land Order No. 7312 (henceforth, PLO 7312), the "Withdrawal of Public Land for the Protection of *Arabis pusilla* Plant Habitat." This order pursuant to Section 204 of the Federal Land Policy and Management Act of 1976, 43 U.S.C. 1714 (1994), withdrew land from "settlement, sale, location, or entry under the general land laws, including the United States mining laws (30 U.S.C. Ch. 2 (1994)), but not from leasing under the mineral leasing laws" on 412.8 ha (1,020 (ac) of Fremont County rockcress habitat to protect the species' occupied habitat (63 FR 9012; February 23, 1998) (see yellow outline in Figure 1). This withdrawal will expire in 50 years (i.e. 2048) unless the Secretary determines that the withdrawal shall be extended. However, energy development and resource extraction do not appear to be currently impacting the species (similarly, our 12-month finding for the species indicated that this stressor was not impacting the species (76 FR 33924; June 9, 2011)). Furthermore, the BLM has the ability through applications for permits to drill to move developers outside of habitat for the Fremont County rockcress. However, because of the uncertainty regarding future resource extraction pressure,

we will evaluate the stressor of resource extraction and mineral development further in our assessment of future scenarios.

3.2.3 Nonnative Invasive Plants

The stressor of nonnative invasive plants was analyzed in the 12 month finding for Fremont County rockcress (76 FR 33924; June 9, 2011). The ecosystem surrounding the area occupied by Fremont County rockcress is primarily sagebrush steppe, which is highly vulnerable to invasions by nonnative invasive species (Anderson and Inouye 2001, pp. 531–532), and this vulnerability may be exacerbated by the effects of climate change (Abatzoglou and Kolden 2011, p. 471). However, surveys conducted by WYNDD in 2003 found the area in which Fremont County rockcress occurs generally free of nonnative invasive species (Heidel 2005, p. 10), and recent reports indicate that the habitat in which Fremont County rockcress occurs has not been invaded by other species (Heidel 2012, p. 15). As noted previously, the restrictive habitat occupied by Fremont County rockcress may limit the potential for competition from other herbaceous plants (Dorn 1990, pp. 6, 8) because plant material is not able to accumulate on the rock outcrop and produce soil. In fact, during previous years of monitoring, *Bromus tectorum* (cheatgrass) has been noted in the surrounding area; however, it has not invaded habitat for Fremont County rockcress (Heidel 2012, p. 15). Dandelion (*Taraxacum*) has been noted as an associated species occurring in trace amounts (Heidel 2012, p. 15), though we do not consider this species to be competing with Fremont County rockcress. We have no information to suggest that nonnative invasive plants are a current stressor to Fremont County rockcress, particularly given the poor soil formation in the occupied patches, which would make it difficult for nonnative invasive plants to colonize the area. Furthermore, few other species occur within the microhabitats occupied by Fremont County rockcress, and the processes that maintain the rock outcrop in a largely unvegetated state are unknown. The exposed rock provides little, if any water-holding capacity, and the lichens covering much of the rock do not provide a surface for colonization (Heidel 2012, p. 15). However, changing climate, with changes in precipitation regime, longer growing season, etc. (further described in **Section 3.2.4 Climate Change**), has the potential to make the habitat in which Fremont County rockcress occurs more vulnerable to invasions by nonnative invasive species, so we will evaluate competition with nonnative invasive plants further in our assessment of future scenarios.

3.2.4 Climate Change

In this SSA Report, we use our expert judgment to weigh relevant information, including uncertainty, in our consideration of various aspects of climate change. In general, it is anticipated that plant species with restricted ranges may experience population declines as a result of climate change. The Intergovernmental Panel on Climate Change (IPCC) Climate Change 2014 Synthesis Report states that "most plant species cannot naturally shift their geographical ranges sufficiently fast to keep up with current and high projected rates of climate change on most landscapes" (IPCC 2014, p. 13). However, areas containing endemics may also provide stable climatic refugia into the future, as evidenced by past climate variations (Harrison and Noss 2017, p. 207).

The current climate of the area where Fremont County rockcress occurs has annual precipitation ranging from less than 20 cm to over 50 cm (<8 to >20 in.), with most of that

precipitation falling as winter and spring snow (NOAA 2016, entire). Because of this, Fremont County rockcress may be adapted to some variation in moisture availability (Dorn 1990, p. 6). Climate change may affect the timing and amount of precipitation as well as other factors linked to habitat conditions for this species. Climate models produce projections of weather patterns into the future, and are limited by the data included in the model and their parameterizations. Nevertheless, for the purposes of the SSA, we use the best available science and information to conduct our assessment, and therefore we use climate models to predict changes in weather into the future. For example, climate models predict that by 2050, the watershed where Fremont County rockcress occurs (Hydrologic unit code 8: Sweetwater, 10180006) will become warmer in all four seasons (USGS 2016 pp. 1–2), but that precipitation will increase in the winter and spring, decrease in summer, and remain about the same in fall (USGS 2016 p. 3). Snow water equivalent, which is a measure of the amount of moisture present in snowfall, will decline in the winter and spring and soil water storage will decline in the summer and fall (USGS 2016 pp. 4–6). A combination of warmer climate and more precipitation in winter and spring could expand the growing season for Fremont County rockcress, particularly because the growing season for this species appears to be currently limited by the number of frost-free days, and because numbers of plants appear to be higher in years with higher than average spring precipitation. However, declines in soil water storage in the summer may limit seed production, which could cause declines in recruitment. Reproductive success in Fremont County rockcress currently varies considerably across years likely due to climate conditions, leading to wide fluctuations in the number of individuals (Dorn 1990, p. 10). Additionally, Fremont County rockcress may be exposed to more extreme weather events, which are predicted to occur more frequently worldwide (IPCC 2014, p. 53). These could include more late spring snow storms, to which Fremont County rockcress could be vulnerable if the plants have already begun their growing cycle, or if weather events produce a combination of conditions that occur outside the species' tolerance range and during a vulnerable life history stage.

The future impact to the species from possible long-term changes in the timing of precipitation and warming trends due to climate change is uncertain, because while some negative effects may occur from drier summers, these may be mitigated by lengthening of the growing season and increases in precipitation at the start of the growing season. While climate change has the potential to affect the species' habitat, it is uncertain what those changes may ultimately mean for Fremont County rockcress. Therefore, we evaluate climate change further in our assessment of future scenarios.

3.2.5 Drought

Limited evidence shows there may be some response of Fremont County rockcress to drought conditions, but those effects may be delayed (Heidel 2012, pp. 17–18). Additionally, it is not known whether Fremont County rockcress has a seedbank that can persist through dry years to ameliorate population reductions in less favorable years (Heidel 2014, p. 4). Reproductive success may vary considerably from year to year depending on climate conditions, leading to wide fluctuations in the number of individuals (Dorn 1990, p. 10). Overall trends in estimates of number of plants appear to track with precipitation levels, where the number of individuals expands in years or following years of high precipitation (see Figure 5), particularly when the majority of the precipitation falls in the spring and summer (NOAA 2016, entire). For example,

we now think that the high number of flowering individuals counted in the 1988 count was actually due to very high precipitation amounts that fell in 1986 (Heidel 2012, pp. 17–18).

The mean annual precipitation at South Pass City (1915-2005) is 34 cm (13.4 in). In 2014, by the end of May, the water year total (a 12-month period from 1 Oct – 30 May) was already at 49 cm (19.4 in). And in 2015, by the end of May, the water year total was already at 52.3 cm (20.6 in). The proportion of non-flowering plants relative to flowering plants was exceptionally high in 2015 (149%; 313 non-flowering plants compared to 210 flowering plants in the expanded plot). It is hypothesized that this reflects the back-to-back years of relatively moist spring conditions and survival and recruitment between them. The high proportion and record high numbers of non-flowering plants in 2015 may reflect these conditions, and bodes well for future flowering plant numbers (Heidel 2016a, p. 6). Therefore, we do not find drought in general to be a current impact at this time, because the species appears to be adapted to periodic drought (Dorn 1990, p. 6). This is likely due, in part, to the ability of individuals to remain in a vegetative state for a number of years without flowering, since flowering requires more water. While individuals may persist for a number of years in a vegetative state, some reproduction must occur throughout the species so that new plants can become established before others die. We are uncertain what the effects would be of a single or multiple extended and severe drought(s), which may be more likely to occur in the future due to a changing climate (Dai 2013, p. 52), and therefore we will evaluate changes in precipitation caused by climate change further in our assessment of future scenarios.

3.2.6 Wildfire

Wildfire has not been considered a stressor to Fremont County rockcress in previous Service documents, and it does not appear that wildfires have affected the species to date. However, wildfires may become more frequent and intense due to changing climate and invasion by fire-prone species such as cheatgrass (Abatzoglou and Kolden 2011, entire). Extended periods of warm and dry conditions make fires easier to ignite, and cause fire seasons to be lengthened, which can increase the risk to habitats such as those in which the Fremont County rockcress occurs. While Fremont County rockcress habitat itself has sparse vegetation and is mainly composed of exposed rock, there are standing dead limber pine trees nearby which may potentially pose a fire risk to Fremont County rockcress. Additionally, should a wildfire occur in the area, it is possible that Fremont County rockcress habitat could be impacted through off-road fire control practices and, due to its exposed rock outcrops, potential use as a natural fire line (Heidel 2012, p. 24). Additionally, a wildfire would likely destroy the wooden exclosure fence, thereby allowing more access for fire control and for recreation until the fence is repaired or replaced. Conversely, a wildfire may also serve to improve available habitat for Fremont County rockcress by removing competing plants and exposing currently covered rock outcrop habitats, thus creating new habitats available for colonization by Fremont County rockcress. Because of the increased potential that wildfires could affect this species in the future through increases in fire season length, fire intensity, and the potential invasion of fire-prone species, we will evaluate this stressor further in our assessment of future scenarios.

3.2.7 Predation and Disease

Grazing has been considered as a potential stressor to Fremont County rockcress in previous Service documents. However, livestock access to the Occurrence 1 has been restricted through conservation actions taken by the BLM, including the establishment of a SRMA and an Area of Critical Environmental Concern (ACEC) that cover all known locations of Fremont County rockcress within Occurrence 1 (BLM 1997, pp. 17-18 and 34, respectively), and the construction and maintenance of an exclosure fence that was built to enclose occupied habitat of the Occurrence 1 and keep livestock out (Dunder 1984, entire; Marriott 1986, p. 14).

Insects, such as caterpillars, do not appear to favor Fremont County rockcress over other vegetation (Heidel 2005, p. 10), and observations during routine monitoring suggest that herbivory from wild ungulates or small mammals may affect some individuals, but do not have a population-level impact. Therefore, we do not consider predation to be a population-level impact to Fremont County rockcress currently, and we have no evidence that it will become one in the future. Additionally, we have no indication that disease is currently impacting, or expected to impact this species. In summary, we do not have any information to suggest that disease or predation is an impact at the population level to this species currently, and we do not expect these stressors to increase into the future. Therefore, we do not evaluate predation and disease further in our assessment of future scenarios.

3.2.8 Small Population Dynamics

Small population size was considered a stressor to the Fremont County rockcress in our 12 month finding (76 FR 33924; June 9, 2011). However, based on additional years of data, and an improved understanding of the species' apomictic reproductive system (see **Section 2.3 Individual-level Ecology**), we now have a different understanding of the implications of small population size with regards to Fremont County rockcress. Small populations can be vulnerable to stochastic events (Barrett and Kohn 1991, p. 7; Oostermeijer 2003, p. 21; O'Grady 2004, pp. 513–514) and genetic drift (Ellstram and Elam 1993, pp. 218–219). The known range of Fremont County rockcress consists of a single occurrence composed of eight suboccurrences, with varying numbers of individuals in each suboccurrence. When compared to other years' monitoring efforts, 2016 and 2011 provide the most complete counts to date, and the data from the original and expanded monitoring plots in suboccurrence 1 in Occurrence 1 provides helpful information regarding trends in that area. The ratio of flowering to non-flowering plants appears to vary widely year to year, and count estimates including only flowering plants underrepresent the total number of individuals in any given year (Heidel 2016b, p. 6) or the reproductive capacity of the occurrence in future years. For example, data collected from the original monitoring plot in 2012 showed a decline compared to 2011 in flowering plants but an increase in the number of non-flowering plants (Heidel 2014, p. ii; Heidel 2016b, p. 5). The number of flowering plants increased slightly in 2015 and 2016 monitoring, and the number of non-flowering plants increased by an even larger amount over the same period (Heidel 2016b, p. 5). Therefore, the total abundance, as characterized by the number of flowering and non-flowering plants, provides the best information to aid in understanding demographic factors affecting the species' resiliency and the effects of small population size.

In previous annual reviews of this species' status through the Candidate Notices of Review (CNORs), we described what appeared to be a downward trend in numbers of individuals. This perceived downward trend was reliant upon the 1988 count as a baseline, though we do not have records to indicate whether 1988 was a typical year or was actually representative of a spike, as

part of normal vacillations in abundance. There is concern that Fremont County rockcress may continue to be vulnerable to periods of prolonged drought or stochastic events. However, the numbers of plants show rebounds in years of higher precipitation following years of drought, indicating that the species may be adapted to relatively wide fluctuations in the number of individuals present on the landscape over time.

The fact that Fremont County rockcress is rare does not necessarily mean that it has low viability. The species has likely persisted within its limited suitable habitat for a long period of time, and due to its hybrid nature, likely has only ever occurred in its present habitat. Many naturally rare species have persisted for long periods within limited geographic areas, potentially due to climate stability (Harrison and Noss 2017, p. 209), and many naturally rare species exhibit traits that allow them to persist despite their low numbers. One example of such a trait for Fremont County rockcress is its apomictic breeding system. Because of the apomictic reproduction system for this species, the limitations associated with inbreeding and limited genetic diversity in small populations likely do not apply to this species. Furthermore, being apomictic can be an advantage in unfavorable climates and areas with unreliable pollinator service such as newly-colonized landscapes, because the likely low carrying capacity of the area selects for reproductive systems that generate few, very fit genotypes (Richards 2003, p. 1088). For other species, apomixis has been shown to reduce extinction risk if certain other variables are present, such as high levels of biomass and no soil acidity (Freville *et al*. 2007, p. 2666). However, information on what apomixis means for conservation of a species remains limited (Freville *et al*. 2007, p. 2669). For example, without recombination, asexualy-reproducing species cannot respond to natural selection as quickly as sexually-reproducing species due to the linkage between beneficial and deleterious mutations (Hill-Robertson interference; Hill and Robertson 1966, entire). Furthermore, any accumulated deleterious mutations in an asexual population cannot be purged, which may result in a decline in population-level fitness (Muller's Ratchet; Felsenstein 1974). In a population with a small effective population size, these factors may increase the evolutionary role of genetic drift relative to natural selection (Lovell 2017, pers. comm.).

Small population size is a condition of the species under which all stressors can be magnified. Fremont County rockcress relies on soils formed from a granite-pegmatite outcrop that is limited in extent, so the range of the species is not likely to expand beyond this area in the future. The relatively small area that Fremont County rockcress occurs within also may predispose the species to be more sensitive to stochastic events (Menges 1990, p. 53; Boyce 1992, pp. 482–484), such as a shift in climate to which the species is not adapted, or factors that lead to reduced reproductive success (Ladyman 2005, pp. 30–31). A single unforeseen event in a relatively small area could theoretically eliminate the species. Stochastic events are, by their very nature, difficult to predict, and the effect on a narrow endemic species is additionally difficult to understand. A species that has always been rare, yet continues to survive, could be well equipped to continue to exist into the future (as with Sleeping Ute milkvetch (*Astragalus tortipes*); USFWS 2015, p. 11), provided that the habitat does not change beyond the range of conditions to which the species is adapted (Harrison and Noss 2017, entire).

A viable population for the Fremont County rockcress may be 500 to 5,000 plants, based on other species of *Boechera*'s demographic constraints and evolutionary history (Ladyman 2005, p. 26), and Occurrence 1 may already fall within this range. However, regardless of the number of individuals within an occurrence at any time, an apomictic species such as Fremont County

rockcress may be able to survive as a species even if low numbers of individuals survive a stochastic event (albeit at much lower levels of the 3Rs), since each individual is capable of reproducing and its offspring capable of recolonizing an area of suitable habitat. Furthermore, this species has likely always had the condition of small population size, and therefore do not consider small population size, in itself to be a stressor to this species. Therefore, we do not evaluate small population size further in our assessment of future scenarios.

3.2.9 Unknown Threat

Previously, the Service considered an "unknown threat" to be contributing to the perceived decline of Fremont County rockcress (76 FR 33924; June 9, 2011). However, our analysis of the available monitoring and precipitation data for the 2016 CNOR (81 FR 87246; December 2, 2016) and this SSA Report suggests that drought cycles may affect individual survival, and may have been the driver of fluctuations in abundance observed in the past. It is possible that in 1988, the year Occurrence 1 was initially counted, the large number of flowering plants observed was the result of greater than average precipitation in 1986. Subsequent monitoring has occurred in drier years, which showed declines, and then in years with high levels of precipitation, which showed increases. We now understand that the data collected at Occurrence 1 suggest that the occurrence may be declining, but may also be fluctuating in response to periods of drought and heavy precipitation, as was described in **Section 3.2.5 Drought**. We expect that Occurrence 1 will continue to fluctuate around a stable mean, with declines during periods of drought, and increases during periods of higher than average precipitation.

The Service has also discussed in previous documents the possibility of a previously unknown disease that may be affecting the species. However, trend information does not show a consistent decline in numbers of plants over time, as would be expected if a disease were spreading throughout the occurrence. Further, no disease was documented in any past monitoring reports. Although rust was documented on a single plant in 2015, it did not appear to be a population-level impact (Heidel 2012, p. 24). Therefore, because no declines are apparent in this species, the Service no longer considers some "unknown threat" to be contributing to the perceived decline of the species, as was suggested in previous years. We will not evaluate the stressor of an "unknown threat" further in our assessment of future scenarios.

3.2.10 Conservation Actions

Several regulatory mechanisms are in place to protect Fremont County rockcress. As described further below, the BLM has designated Fremont County rockcress as a sensitive species, developed a habitat management plan for the species, excluded grazing and off-road vehicle access from the area surrounding Occurrence 1, designated that area as an ACEC, and incorporated it into a SRMA (BLM 2002, entire). Additionally, the Secretary of the Interior removed the area surrounding Occurrence 1 from mineral development under PLO 7312 (63 FR 9013; February 23, 1998) (see yellow outline in Figure 1) until 2048. The Service had previously published a notice of review in 2000 removing Fremont County rockcress as a candidate species for protections under the Act, largely based on protections provided by these regulatory mechanisms and land management approaches, as explained further below (65 FR 63044; October 20, 2000). The purpose of including conservation actions in this SSA Report is to assist with describing the current condition of the species, and is not intended to make management recommendations for this species.

Bureau of Land Management
The BLM designated the Pine Creek Special Recreation Management Area (SRMA) in 1978 (Heidel 2005, p. 16) and built an exclosure fence in 1982 to keep cattle out of the 35.6-ha (88-ac) area where recreational activities occur (Dunder 1984, entire). The fenced area protects all of the known occupied habitat, and in fact restricts access to the entirety of Occurrence 1. The BLM provided a Habitat Management Plan for Fremont County rockcress (BLM 1994, entire) and processed an emergency closure of vehicle access to 202.3 ha (500 ac) in a Habitat Management Area for the species in 1994 (59 FR 17718; April 14, 1994). In addition to these measures, Fremont County rockcress was listed as a BLM sensitive species in 2002 (BLM 2002, p. 9). The BLM 6840 Manual requires that Resource Management Plans (RMP) should address sensitive species, and that implementation "should consider all site-specific methods and procedures needed to bring species and their habitats to the condition under which management under the Bureau sensitive species policies would no longer be necessary" (BLM 2008, p. 2A1).

The Federal Land Policy and Management Act of 1976 mandates Federal land managers to develop and revise land use plans. The RMPs are the basis for all actions and authorizations involving BLM-administered lands and resources (43 CFR 1601.0-5(n)). The 1997 Green River RMP, which is the latest version, provided designation of a Special Status Plant ACEC and formalizes the SRMA described above:

> The ACEC closed the area to:
> (1) direct surface-disturbing activities,
> (2) mining claims,
> (3) surface occupancy and surface-disturbance activities,
> (4) mineral material sales, and
> (5) use of explosives and blasting (BLM 1997, p. 34).
>
> The SRMA provides the following protections:
> (1) prohibited major facilities (e.g., power lines),
> (2) closed the area to mineral leasing,
> (3) closed the ACEC to ORV use, and
> (4) required avoidance and extensive planning of long, linear facilities (e.g., roads) (BLM 1997, pp 17–18).

All activities concerning Fremont County rockcress in the RMP have been implemented. The next Green River RMP revision is currently underway, with a draft of the available for review and comment by the end of fiscal year 2017. The estimated completion date of the Green River RMP is 2019 (Snyder, 2017, pers. comm.). Existing protections for the species will likely remain in place in the revised RMP as a no-action, preferred alternative under National Environmental Policy Act (NEPA), though additional protections for Fremont County rockcress may be developed and included.

Public Land Order No. 7312
On February 23, 1998, the Secretary of the Interior issued PLO 7312 to withdraw public land from certain uses for 50 years as a measure to specifically protect Fremont County rockcress. This order withdrew 412.8 ha (1,020 ac) from settlement, sale, location of minerals, or entry

under the general land laws, including mining laws; this did not eliminate the area from being leased under the mineral leasing laws (63 FR 9012; February 23, 1998). This order expires in 2048 unless it is renewed.

National Environmental Policy Act
The single known occurrence of Fremont County rockcress is on Federal land. All Federal agencies are required to adhere to the NEPA for projects they fund, authorize, or carry out. The Council on Environmental Quality's regulations for implementing NEPA (40 CFR 1500–1518) state that agencies shall include a discussion on the environmental impacts of the various project alternatives, any adverse environmental effects which cannot be avoided, and any irreversible or irretrievable commitments of resources involved (40 CFR 1502). Additionally, activities on non-Federal lands are subject to NEPA if there is a Federal nexus. The NEPA is a disclosure law, and does not require subsequent minimization or mitigation measures by the Federal agency involved. Although Federal agencies may include conservation actions for sensitive species as a result of the NEPA process, any such measures are typically voluntary in nature and are not required by the statute.

In summary, because Occurrence 1 is located on BLM lands, this agency has responsibility for the land management decisions that protect the species and its habitat. Fremont County rockcress receives protections from the BLM in the form of regulatory mechanisms, designations, and the construction of animal and human exclosures. These protections dictate the amount of disturbance that can occur within the plant's limited range. Although these mechanisms do not entirely exclude the location of Occurrence 1 from foot traffic, they have reduced this potential stressor and have removed ORV traffic from Occurrence 1 since the 1980s. As a result, disturbance may potentially impact Fremont County rockcress at the individual level, but is unlikely to affect resiliency at the occurrence level. Given BLM's regulatory mechanisms as well as PLO 7312, we expect that Fremont County rockcress and its habitat will be generally protected from direct human disturbance.

3.3. Current Condition

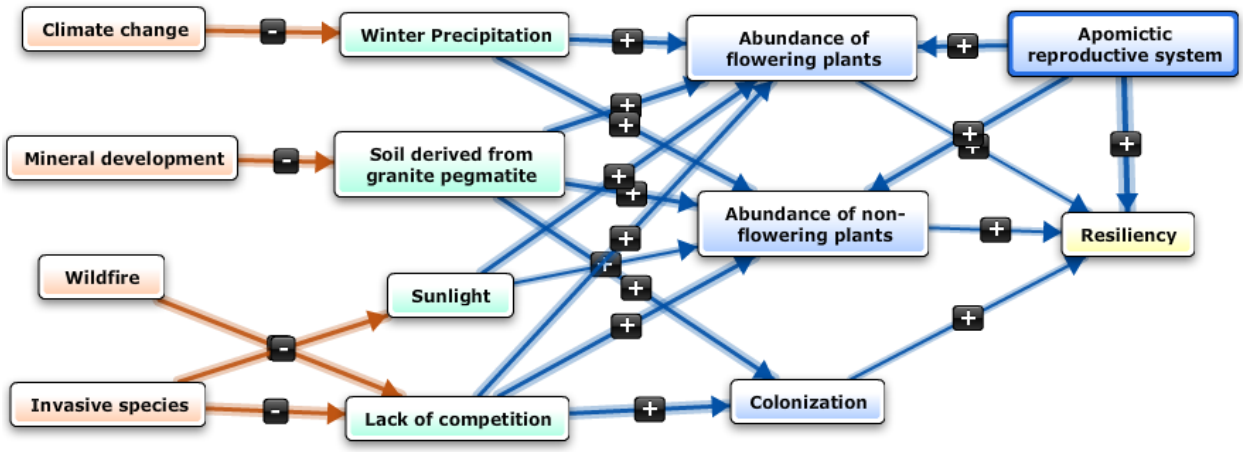
3.3.1 Resiliency

Resiliency is the ability of populations to tolerate natural, annual variation (stochasticity) in their environment and to recover from periodic disturbance. Levels of resiliency, therefore, may be indicated by various demographic and habitat metrics. Typically, under the SSA Framework (USFWS 2016, entire), we assess resilience at the population level, and it is measured based on the number of individuals, or other demographic or habitat factors. However, given the apomictic nature of the species, where each individual reproduces asexually without the need for other individuals and may represent its own microspecies, we also assess the current condition of individuals in our analysis of resiliency. To assess the resiliency of Fremont County rockcress at the individual and population levels, we analyzed the presence of important habitat-based resource needs at the individual level and at the population-scale, namely precipitation, soil derived from granite-pegmatite, and freedom from competition, as well as specific demographic factors of abundance of flowering and non-flowering individuals and colonization at the population level. These factors were identified in **Section 2.3 Individual-level Ecology** and **2.4 Population-level Ecology** as important resources and factors affecting resiliency at the

individual and population levels, respectively. Next, we assessed how the apomictic reproductive system for the species plays a role in affecting resiliency (see Figure 6). Finally, we reviewed the potential stochastic events that may play a role in affecting the viability of the species.

Table 3 presents our characterization of high, moderate, and low resiliency for demographic (flowering and non-flowering abundance and colonization) and habitat (soil, precipitation, and competition) factors affecting the occurrence of Fremont County rockcress. In terms of how abundance affects resiliency, we do not have specific information on historical records of this species or what makes a viable population, though for other species in the *Boechera* genus, a viable population may be between 500 and 5,000 individuals (Ladyman 2005, p. 26). In this analysis, we make the educated assumption that an occurrence consisting of more than 800 flowering individuals indicates high resiliency. This number falls within the 500 to 5,000 individual range mentioned above, and is also based on the species abundance estimates that have been generated by WYNDD with some regularity since 1988. Abundance of flowering plants in Occurrence 1 has ranged from 150 to 1669 individuals, and the count in 1988 of 800 individuals is the benchmark upon which all assessments of population trends since that time have been based.

Figure 6. Conceptual model of factors affecting resiliency for Fremont County rockcress**.** Occurrence-level resiliency is affected by the demographic factors of abundance of flowering and non-flowering individuals and colonization, which are in turn affected by habitat factors. Stochastic events can directly influence habitat factors, which in turn affect demographic factors, impacting the level of resiliency. The apomictic reproductive system contributes directly to the demographic factors and resiliency of the occurrence.



In terms of non-flowering plant abundance, this number can include new recruits into the population as well as adult plants that are non-reproductive in a given year. The locations of individual plants within the suboccurrences of Fremont County rockcress are not identical from year to year, and so it is likely that seeds spread and germinate in unpopulated areas of suitable habitat. Assessing the number of new germinants in a population is difficult to achieve, and due to the extreme difficulty in finding them due to their size, seedlings have never been recorded in monitoring reports. Therefore, we use the number of vegetative, non-flowering plants in the original monitoring plot in suboccurrence 1 of Occurrence 1 to provide the best available information about the status of the occurrence. The original plot in Occurrence 1 has

been monitored with more regularity than the rest of the occurrence overall, and abundance there has ranged from 20 to 671 individuals. Therefore, we are also making the educated assumption that having more than 100 vegetative, non-flowering plants in the original plot is an indication of high resiliency, assuming that for most years, the occurrence has at least moderate resiliency. In our analysis, low resiliency at the occurrence level is therefore represented by numbers lower than the lowest numbers observed, assuming that Occurrence 1 is at least moderately resilient in its current state given its persistence on the landscape (see Table 3). When added together, the number of flowering and non-flowering individuals in any year provides a quantification of the total abundance of an occurrence, and if the number increases over time, then birth rates exceed death rates, and we can presume that some level of recruitment is occurring.

Finally, we note that there is potential for additional occurrences to be discovered in the surrounding area, and these unknown occurrences could potentially provide additional protective support in response to a stochastic event. However, surveys in the surrounding area have not found other occurrences of Fremont County rockcress. Because we have no way of knowing whether additional occurrences do in fact exist, we cannot consider them in our assessment of resiliency. Regarding colonization, Fremont County rockcress is composed of a single known occurrence: Occurrence 1 consists of eight suboccurrences. Therefore, we classify colonization as high if there are more than two suboccurrences in an Occurrence, moderate if there are two suboccurrences, and low if there is only a single area colonized with potential habitat uncolonized nearby. Because we have limited information on what makes occurrences resilient, our assessment of resiliency is based on several assumptions about existing conditions, and documentation that the species continues to persist on the landscape.

Table 3. Current condition assessment for resiliency

	Demographic factors			Habitat factors		
Condition category	Flowering plant abundance	Non-flowering plant abundance	Colonization	Soil derived from granite/pegmatite	Sufficient precipitation	Freedom from competition
High	Total ≥800	≥100 vegetative plants in original plot	>2 suboccurrences	Not limiting (abundant)	Not limiting (abundant)	Not limiting (abundant)
						No impacts from other plants
Moderate	Total >200<799	20–99 vegetative plants in original plot	2 suboccurrences	At times limiting	At times limiting	At times limiting
						Some impacts from other plants
Low	Total ≤200	≤20 vegetative plants in original plot	1 occurrence with no division	Limiting or absent	Limiting or absent	Frequently limiting
						Habitat crowded out with other plants

Regarding the habitat factors contributing to resiliency at the population-scale, we assess the availability of soil that is derived from granite-pegmatite, the sufficiency of precipitation to

sustain germination and survival, and the freedom from competition within the occupied habitat of the Fremont County rockcress. These factors were identified as resource needs at the individual- and population-level in **Sections 2.3 Individual-level Ecology** and **2.4 Population-level Ecology**, respectively. Fremont County rockcress appears to be a narrow endemic species with highly specialized resource needs that constrain the species' occurrence to a small area on the landscape, and so we assess whether resource needs are limiting at a population-scale instead of at a landscape-scale. High resiliency in terms of soil availability is achieved if there are no limitations on soil; moderate resiliency occurs when soil is limiting at times, and low resiliency occurs when soil is limiting or absent. In terms of precipitation, abundant precipitation leads to high resiliency, precipitation limited at times leads to moderate resiliency, and limiting or absent precipitation during important life history events leads to low resiliency. We do not have information to quantify the amount of soil or precipitation needed to achieve each category of high, moderate, or low, but presume that the current status of these resources is sufficient due to the persistence of the species on the landscape. In terms of competition, we assess an occurrence as having high resiliency when there is no competition and no other plants affecting the ability of Fremont County rockcress plants form obtaining needed resources, moderate resiliency when some other plants are at times limiting the Fremont County rockcress from obtaining other resource needs, and low resiliency when Fremont County rockcress habitat is crowded with other species and resources are difficult to obtain (Table 3).

The apomictic reproductive system of Fremont County rockcress allows for individual plants to reproduce asexually through seed production. Hybrid apomicts tend to be highly adapted to their environment (Richards 2003, p. 1088), and therefore, offspring produced by mother plants are likely to be highly adapted to the environment as well. Reports of the habitat for Fremont County rockcress indicate that the habitat is likely quite stable and has been for recent geologic past (Heidel 2016b, p. 7). As long as the environment continues to fall within the range of suitability for the Fremont County rockcress, it is likely that the species will continue to occur in those habitats. Furthermore, because of the removal of limitations on reproduction caused by lack of pollinator service or small population size, apomixis allows individuals to directly drive abundance, and therefore directly affects the resilience of populations in this species.

Our evaluation did not identify any stressors that are currently having an impact on resiliency of Occurrence 1 of Fremont County rockcress. Climate change does not appear to have affected the species to date, and we expect Fremont County rockcress to be highly adapted to the present, highly variable climate of its habitat due to its apomictic reproductive system. It is possible that mining has affected individuals and removed suitable habitat for the species in the past, though there is no current resource extraction or energy development within the vicinity of either occurrence. Wildfire has not occurred within the habitat for Fremont County rockcress based on historical records of the area. Nonnative invasive species do not currently affect the resiliency of Fremont County rockcress, because no competing plants have been able to colonize the rocky substrate in which Fremont County rockcress occurs.

Therefore, using the conditions quantified in Table 3, we classified the current resiliency for the single occurrence of Fremont County rockcress (see Table 4). For Occurrence 1, we rate it as having high abundance of flowering plants, moderate abundance of non-flowering plants, high colonization, high soil availability, high precipitation, and high freedom from competition factors. This results in Occurrence 1 having an overall condition of high resiliency at present.

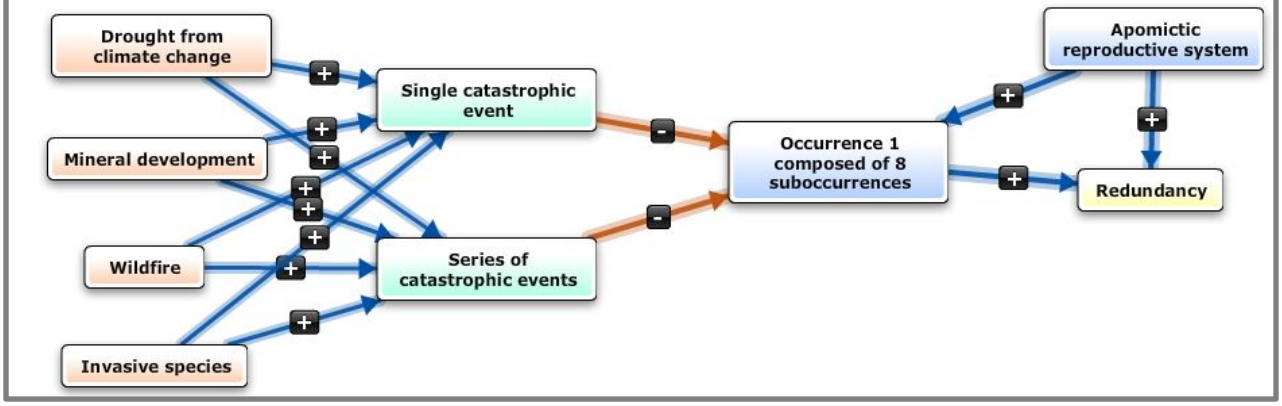
Table 4. Resiliency classification for Occurrence 1. Colors are representative of the values assigned for high, moderate, and low resiliency in Table 3. Numbers represent values measured in 2016 monitoring. Occurrence1 is characterized as having high resiliency.

	Demographic factors			Habitat factors			
Occurrence Number	Flowering plant abundance	Non-flowering plant abundance	Colonization	Soil derived from granite/pegmatite	Sufficient precipitation	Freedom from competition	Overall Condition
Occurrence 1	1,600	52 vegetative plants in original plot	8 sub-occurrences	Not limiting (abundant)	Not limiting (abundant)	Not limiting (abundant) No other plants	Highly resilient

3.3.2 Redundancy

Redundancy is the ability of a species to withstand catastrophic events. It is measured by the number and distribution of populations across the range of the species. Figure 7 provides a conceptual model of the factors affecting the redundancy of Fremont County rockcress. Fremont County rockcress has a single known occurrence, which does not provide much protection for a catastrophic event. While it is possible that additional undiscovered occurrences could exist, we cannot rely on them in assessing redundancy. Occurrence 1 contains eight suboccurrences that are distributed across a small area. A single catastrophic event or a series of catastrophic events could potentially negatively affect one or more suboccurrence within Occurrence 1 or could completely eliminate the species if it spans the entire species' range. Stressors that may be considered to be catastrophic events or affect the Fremont County rockcress on a catastrophic level could include drought from climate change, mineral development, wildfire, or a dramatic increase in invasive species (see Figure 7). As far as we are aware, no catastrophic events have occurred to date to eliminate individuals or occurrences of Fremont County rockcress. It is possible that resource extraction in the past could have removed an undiscovered occurrence, but we have no information to indicate that has happened. It is unlikely that a catastrophic event would remove the entire species from the landscape given the protections currently in place.

Figure 7. Conceptual model of factors affecting redundancy of Fremont County rockcress. The single known occurrence with 8 suboccurrences contributes to redundancy of the species. Catastrophic events can negatively affect the single occurrence. The apomictic reproductive system of the species can contribute to the resiliency of the single occurrence, and affect redundancy of the species.



We assume that the current distribution of occurrences is what is needed to reduce the risk from catastrophic events. Suboccurrences are expected to remain distributed in their current locations in the long-term, particularly because the species appears to have always occurred within its present habitat, which is static and appears unchanged in recent geologic time. These suboccurrences are not expected to move, though there is potential for seeds to be carried to nearby unoccupied suitable habitat. Uncertainty regarding redundancy includes whether and how a catastrophic event can affect the single known occurrence. We do not know the level of connectivity among individuals (due to apomixis), much less among suboccurrences, or if connectivity is even meaningful since each individual acts as its own agamospecies or microspecies.

Under the SSA Framework (USFWS 2016, entire), we typically assess redundancy at the species level (e.g. based on how many populations a species has, how resilient they are, and how they are distributed). Based on this assessment of redundancy, the Fremont County rockcress has a single highly resilient occurrence, which results in low species-wide redundancy, similar to many narrow endemic species.

However, because Fremont County rockcress is apomictic and each individual can be considered a microspecies, even individuals can contribute to the species' ability to withstand catastrophic events, because they may produce offspring to repopulate an area of suitable habitat following a catastrophic event. Therefore, it is possible that for this species, redundancy can be also assessed based on the number of individuals distributed spatially within an occurrence. If assessed as the number of individuals distributed spatially within an occurrence, the species is characterized as having over 1,600 individuals (as of the 2016 monitoring) spread across eight locations (suboccurrences 1 through 8 in Occurrence 1) within an approximately 7.2-ha (18 ac) area. While small on a geographic or landscape scale, this area represents much of the suitable habitat for the species (Andersen *et al*. 2016, Appendix 2, pp. 151-154). While still only covering a small geographic area, the Fremont County rockcress may be assessed as having moderate redundancy when including the number of individuals in addition to the number of populations in the analysis.

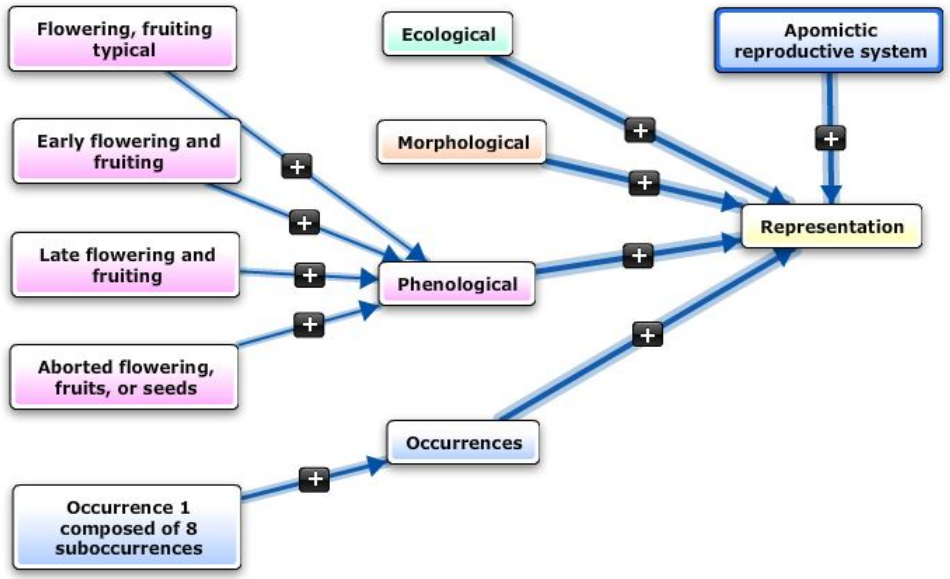
3.3.3 Representation

Representation is the ability of a species to adapt to changing physical (climate, habitat) and biological (diseases, predators) conditions. It can be thought of as the 'adaptability' of the species. Representation is often measured in terms of genetic diversity. However, we lack genetic information for Fremont County rockcress. Therefore, as a surrogate for measuring the breadth of diversity within the species, we explore and evaluate other potential and apparent forms of representative diversity. In this case, the species may be represented by a single known occurrence, occupying one ecological setting, including potential for morphological variants, and four phenological stages (see Figure 8).

These other forms of potential and apparent diversity may not comprise much variation within the species, given the subtly perceptible differences among them. However, as is the case with many narrow endemics, it is likely that the species does not have, and has never had, very high levels of representation on the landscape due to its relatively recent evolution and due to the fact that offspring of a mother plant are clones of that plant, or nearly so. Furthermore, Fremont County rockcress is highly adapted to its environment, and so it is likely unable to adapt to

changes in the environment outside of its realized niche. Nevertheless, we here attempt to discuss and describe all potential sources of diversity and variation within the species.

Figure 8. Conceptual model of factors contributing to representation of Fremont County rockcress. Ecological, morphological, phenological, and occurrence variation contribute to the representation of the species. The apomictic reproductive system also contributes to the representation of the species.



Because the species is apomictic, it likely is highly adapted to its current environment, similar to other apomictic species (Richards 2003, p. 1088), which may make the Fremont County rockcress less able to adapt to changing environments. While apomixis involves asexual reproduction through seeds, and seeds produced through this mechanism are theoretically clones of the mother plant, it is possible that some recombination occurs and that some genetic differences occur between mother and daughter plants (van Dijk *et al*. 2009, p. 53). Furthermore, because the species is triploid, and most apomictic species are highly heterozygous, Fremont County rockcress likely has the capability for some level of phenotypic plasticity (Richards 2003, p. 1087), which could allow for some adaptability within individuals if conditions change. We have limited information on the genetic variability of the species, but microsatellite analysis of 15 loci found three alleles for most loci, and that variation only occurs

in the two most rapidly evolving loci, which suggests the samples were all taken from individuals resulting from a single hybridization event (Windham 2016, pers. comm.).

The ecological representation that currently characterizes this species is that it is found in a single ecological setting composed of three microhabitats: granite outcrops, gravel pavement, and the margins of the granite outcrop and gavel pavement. These microhabitats are highly intermixed within each occurrence, and there is likely little diversity among the actual microhabitats themselves. While these three microhabitats occur in close proximity to each other within the small area that constitutes the species' habitat, the species expresses some plasticity in colonizing these areas, which may provide information on the current breadth of diversity within the species.

Another potential method of assessing representation is through morphological differences among members of the species. Morphological differences among individuals documented in the field are minimal. Because the Fremont County rockcress is apomictic, offspring are either clones of or are very similar to the mother plant, though there is potential for some variation to occur through phenotypic plasticity. Therefore, there is potential for some morphological variation within the species, but we lack information about that at this time.

In terms of phenology, the individuals within the species may express underlying variation by the timing in which a plant flowers, fruits, and sets seed, or by not reproducing in a given year. These phenologies are: typical timeframe, earlier than usual timeframe, later than usual timeframe, or aborted reproduction. Because not all plants within an occurrence have identical phenologies, these altered phenologies may express phenotypic plasticity that is the result of genetic variability and the ability to adapt to change.

Finally, the species is represented by a single known occurrence, and we note that there is the potential for additional, unknown occurrences around this location, although we cannot rely on any potential undiscovered sites as contributors to representation. The separation of the suboccurrences within Occurrence 1 provides some indication that the species has been and likely continues to be capable of colonizing new areas, and suggests that the species has some ability to adapt to a changing environment or colonize areas not currently occupied should they become suitable in the future. We have only ever known of a single occurrence, and in 2001, removed the species from the candidate list due to the stability of that single occurrence and the protections put in place by BLM to protect the species (BLM 1997, pp. 17–18, 34).

In summary, a comprehensive evaluation of representation in the Fremont County rockcress is not possible given the limited genetic data available. There may be minor ecological, morphological, phenological, or other differences between individuals or between suboccurrences that could indicate some diversity and contribute to representation. However, given that the species is a narrow endemic plant occurring across a small area, and given that offspring are near clones of their parent due to the apomictic reproductive system, it is possible that the species may not have, and may never have had a high level of representation. Overall, we characterize the Fremont County rockcress as having low representation.

3.3.4 Synthesis of Current Condition

In summary, Fremont County rockcress currently consists of a single known occurrence that is confined to a small area due to the specific habitat requirements of this species. Fremont County rockcress reproduces asexually through apomixis, which may reduce the hazards of small population size, and theoretically could allow for the species to withstand stochastic and catastrophic events even if few individuals survived, although it would be left with reduced levels of the 3Rs. We understand that the number of individuals in Occurrence 1 has fluctuated over time, and that the number of individuals in any given year appears to be correlated with climate conditions, and namely precipitation, two years prior. The species was potentially negatively impacted by recreation prior to the installation of an exclosure fence, and potentially would have been impacted by resource extraction and mineral development if not for the BLM and PLO 7312 offering protection to Occurrence 1. Other stressors do not appear to be negatively impacting Fremont County rockcress currently, but there is potential that they may impact the species in the future.

Resiliency of populations is currently measured by the ability of populations to respond stochastic events. Fremont County rockcress is currently characterized as having one occurrence (Occurrence 1) with high flowering and non-flowering plant abundance and colonization demographic factors, as well as high soil and precipitation conditions, and freedom from competition. The current status and trends of the flowering and non-flowering plant abundance and colonization of Occurrence 1 indicates that this occurrence of Fremont County rockcress is highly resilient. Table 5 provides a visual summary of the factors contributing to the current resiliency of this occurrence.

Table 5. Current condition of Fremont County rockcress. Resiliency is taken from Table 4, where Occurrence 1 has high resiliency overall. Redundancy and representation are characterized at the species level. Green indicates high condition, yellow indicates moderate condition, and red indicates low condition. Conservation actions and lack of threats contribute to the overall condition of the species.

Current Condition	Resiliency								
	Demographic factors			Habitat factors					
Occurrence Number	Flowering plant abundance	Non-flowering plant abundance	Colonization	Soil derived from granite/ pegmatite	Precipitation	Freedom from competition	Overall Condition	Redundancy	Representation
Occurrence 1									

Redundancy, or the ability to withstand catastrophic events, in Fremont County rockcress is presently characterized by a single occurrence that is composed of eight suboccurrences that are spread approximately 1,100 m (3,600 ft) apart. Therefore, based on an assessment at the population level, the Fremont County rockcress has low redundancy. However, while we typically measure a species' redundancy based on the number and distribution of its populations, in this case, individual plants may also contribute to the species' ability to withstand catastrophic events. The apomictic nature of the species may help provide additional protection in case of catastrophic events because each plant is capable of producing offspring

asexually, and therefore each individual plant may be considered an agamospecies or microspecies. Therefore, the species theoretically could withstand a catastrophic event even if a few or even a single individual survived, although at much reduced levels of the 3Rs. Fremont County rockcress is currently estimated to have over 1,600 individuals distributed among nine spatial distinct areas within an approximately 7.3 ha (18 ac) area, and so we consider the species to presently have moderate redundancy, even though there is only a single occurrence of the species.

Representation of Fremont County rockcress is characterized through assessment of ecological, morphological, phenological, and occurrence representation. We found minor differences across the species in ecological, morphological, and phenological characteristics. The limited genetic data available suggest that the individuals comprising this species are nearly genetically identical. However, because this species is a hybrid triploid, and most apomictic species are highly heterozygous, it is likely that individual plants are capable of expressing different traits in response to differing conditions, and therefore individuals may be highly adaptable, which may help the species persist through changing conditions. Therefore, at present, we consider Fremont County rockcress to have low representation, but with some adaptability provided by its apomictic nature. However, it is likely that the species, like many narrow endemics, never had high representation due to its geologically recent evolution and narrow niche.

When taken together, the current condition of Fremont County rockcress is characterized by varying levels of the 3Rs. That is, Occurrence 1 has high resiliency; redundancy is low when measured at the population level but moderate when considering redundancy provided by individuals; and representation is low, although individuals may themselves have some plasticity and adaptability. However, we consider the species overall to currently to be doing well, despite it being a narrow endemic plant with a highly specialized habitat requirement, which is in part due to the special way in which this species reproduces. This is also due in large part to the lack of threats affecting the species, current apparent stability of the species, and conservation actions on the ground.

Chapter 4. Analysis of Future Conditions

4.1 Introduction to Future Scenarios

Based on the analysis of potential stressors affecting the species historically, currently, and into the future in **Section 3.2 Factors Affecting Current Condition**, the stressors of energy development and resource extraction, nonnative invasive plants, climate change, drought, wildfire, and a combination of these factors are considered to be risk factors with the potential to affect Fremont County rockcress into the future. We discussed each stressor's impact on the current condition of the species in that section, and we determined which stressors can plausibly continue or begin impacting the Fremont County rockcress in the future. We expect the level of impact resulting from the stressors to change based on the effects of climate change and based on the expected duration of conservation measures presently in place.

We also considered whether conservation actions in the future have the potential to minimize impacts of stressors affecting the Fremont County rockcress (see Table 6). We presume that the ongoing protections in place due to the species' location on BLM lands will continue at

current levels, and thus incorporate them into our future scenarios. Other potential future conservation actions that we considered vary in their likelihood of occurring, from very likely (directing mineral development outside of habitat) to unlikely (watering plants). Additionally, none of the potential conservation actions are mandated to begin, such as watering plants or pulling invasives, or to be renewed, as in the case of PLO 7312. We also make no assumptions about the practicality or feasibility of suggested conservation actions, or their effects on the species if they are implemented. Therefore, while these possible conservation actions are mentioned for the sake of exploring all potential possibilities, when assessing the effect of the stressors in the future, we do not include the mitigating effect of the potential conservation actions, and instead rate the predicted future condition of each occurrence in each scenario as though no additional conservation actions have been implemented.

Non-climate-dependent, but potentially climate-linked, stressors include invasion by highly competitive native or nonnative invasive plants, mineral development, and wildfires (see Table 6). We are uncertain of the future impacts of these stressors on Fremont County rockcress, and so we provide a range of plausible impacts for each stressor. For example, we analyze the future impact of mineral development at three levels: no mineral development, some mineral development nearby, and mineral development occurs within the occupied habitat of Fremont County rockcress. The impact of mineral development can be mitigated in the future if the PLO 7312 is renewed and expanded to limit mineral development within either occurrence of the species, and so this conservation action is included as a possibility in our analysis of future condition.

Table 6. Stressors potentially affecting Fremont County rockcress into the future, along with anticipated changes in stressors over time. The effect of each stressor and potential conservation actions to mitigate the effects of stressors are provided.

Stressor	Anticipated change in stressor	Effect of stressor on resources or demographic factors	Potential conservation actions
Change in precipitation caused by climate change	Decreased amounts of precipitation Altered timing of precipitation	Reduced germination Reduced survival	Provide water during crucial times
Invasion by highly competitive plants	Increased invasions	Reduced dispersal Reduced vigor	Pull invasives
Mineral development	Increased mineral development	Reduced dispersal Mortality	Public Land Order 7312 (through 2048 ~30 yrs) Direct development outside of habitat
Wildfire	Increased frequency of wildfires	Reduced survival Mortality	Pull invasives and remove woody debris

We assessed two time frames for characterizing the condition of Fremont County rockcress into the future. We selected the years 2050 and 2100 based on the available information contained in climate predicting models provided through the USGS Climate Change Viewer, Summary of Sweetwater, Wyoming (8 digit HUC: 10180006) (USGS 2016, entire). The time

frames of 2050 and 2100 are biologically relevant for this species because they will capture approximately 10 and 40 generations of Fremont County rockcress, respectively (assuming that a plant typically produces offspring in its second year), which is a timeframe in which we would expect to be able to observe changes in the condition of the species.

4.2 Scenarios

For each of the two time frames (2050 and 2100), we assessed three future scenarios: continuation, best case, and worst case. These scenarios include data from representative concentration pathways (RCP) of greenhouse gas (GHG) concentration trajectories adopted by the IPCC in the Fifth Assessment Report (AR5) in 2014 (see Table 7; IPCC 2014, entire). The four RCPs: RCP 2.6, RCP 4.5, RCP 6, and RCP 8.5, are named after a possible range of values of solar energy radiated back to space minus absorbed by the Earth in the year 2100 relative to pre-industrial values (+2.6, +4.5, +6.0, and +8.5 Watts per square meter (W/m^2), respectively), which are consistent with a wide range of possible changes in future anthropogenic (i.e., human) greenhouse gas (GHG) emissions. We are not assessing the likelihood of each of these possible changes due to the unknown trajectory of GHG emissions.

The continuation scenario, representing the continuation of current rates of change, is based on emissions in RCP 4.5, which predicts that emissions will peak around 2040, and then decline. Projections for RCP 4.5 indicate increases from current temperature: 1.4°C (2.52°F) increase by 2050 and 1.8°C (3.24°F) increase by 2100 (see Table 7) for the area where Fremont County rockcress occurs. The best case scenario is based on RCP 2.6, which assumes that global annual GHG emissions (measured in CO_2-equivalents) have peaked or will peak between 2010-2020, with emissions declining substantially thereafter. Projections for RCP 2.6 indicate a 1°C (1.8°F) increase from the current temperature by both 2050 and 2100 (See Table 7). The worst case scenario is based on RCP 8.5, in which emissions continue to rise throughout the 21st century. Projections for RCP 8.5 indicate increases from current temperatures: a 2.0°C (3.6°F) increase by 2050 and a 3.7°C (6.66°F) increase by 2100 (see Table 6). The USGS Climate Change Viewer for the local area (8 digit HUC: 10180006) only provides GHG emissions trajectories for RCP 4.5 (continuation scenario) and RCP 8.5 (worst case scenario), and so we predict that the RCP 2.6 (best case scenario) would have substantially lower GHG emissions and a nearer to flat trajectory.

Table 7. IPCC AR5 global warming increase projections in degrees Celsius at the various RCP scenarios. Based on Table SPM.2 (IPCC 2013).

	2046-2065	**2081-2100**
Scenario	**Mean and *likely* range**	**Mean and *likely* range**
RCP2.6	1.0 (0.4 to 1.6)	1.0 (0.3 and 1.7)
RCP4.5	1.4 (0.9 to 2.0)	1.8 (1.1 to 2.6)
RCP8.5	2.0 (1.4 to 2.6)	3.7 (2.6 to 4.8)

Changes in precipitation are expected with climate change as well. As discussed under **Section 3.2.4 Climate Change**, snow water equivalent, which is a measure of the amount of moisture present in snowfall, will decline in the winter and spring, and soil water storage will decline in the summer and fall (USGS 2016 pp. 4–6). The declines in soil water storage may limit seed

production, which could cause declines in recruitment, and could limit areas suitable for colonization. Insufficient precipitation during any season could also lead to mortality of individual plants and decrease overall occurrence abundance. However, a combination of warmer climate and more precipitation in winter and spring could expand the growing season for Fremont County rockcress, particularly because the growing season for this species appears to be currently limited by the number of frost-free days, and because numbers of plants appear to be higher in years with higher than average spring precipitation.

The scenarios assessed for the future condition of Fremont County rockcress are included in Table 8. The continuation, best case, and worst case scenarios are each assessed at the 2050 and 2100 time frames, and include predicted changes to climate based on the AR5 global warming increase projections, and changes to other stressors that may affect Fremont County rockcress in the future. Conservation actions that could hypothetically be implemented to mitigate the impacts of the projected stressors are noted, but are not considered in our assessment.

Table 8. Summary of factors affecting Fremont County rockcress under future scenarios at the 2050 and 2100 time frames, including effects of climate change and other stressors. Potential conservation actions that could hypothetically be implemented are also noted, but are not considered in our assessment.

2050

Scenario	Climate change	Other stressors	Conservation Actions
Continuation	Emissions continue to rise based on RCP 4.5, peaking approximately 2040 and then declining. Summer air temp increases 1.4°C (2.52°F). Winter snow water equivalent decreases 0.5 cm (0.2 in).	Longer growing season Fewer germinants survive winter Invasives rarely establish Minerals not developed Wildfire kept at bay due to low fuels	Pull invasives if they establish Renew PLO 7312 in 2048 Remove woody debris
Best case	Emissions rise based on RCP 2.6, peaking between 2010 and 2020, and then substantially declining. Summer air temp increases 1°C (1.8°F). No change in winter snow water equivalent.	Similar length growing season Germinants survive winter at current rates No invasives Minerals not developed Wildfires nonexistent	See continuation scenario
Worst case	Emissions rise based on RCP 8.5, where they rise continually throughout the century. Summer air temp increases 2°C (3.6°F). Winter snow water equivalent decreases 0.76 cm (0.3 in).	Much longer growing season Very few germinants survive winter Invasives outcompeting Minerals developed nearby Wildfire occurs	Provide water year-round Pull invasives regularly Renew PLO 7312 in 2048 Remove woody debris

2100

Scenario	Climate change	Other stressors	Conservation Actions
Continuation	Emissions continue to rise based on RCP4.5, peaking approximately 2040 and then declining. Summer air temp increases 1.8°C (3.24°F). Winter snow water equivalent decreases 1.27 cm (0.5 in).	Longer growing season Fewer germinants survive winter Invasives rarely establish Minerals not developed Wildfire kept at bay due to low fuels	Provide water during key seasons (W) Pull invasives if they establish Renew PLO 7312 in 2048 Remove woody debris
Best case	Emissions rise based on RCP2.6,	Similar length growing season	See continuation scenario

	peaking between 2010 and 2020, and then substantially declining. Summer air temp increase 1°C (1.8°F). No change in winter snow water equivalent.	Germinants survive winter at current rates No invasives Minerals not developed Wildfires nonexistent	
Worst case	Emissions rise based on RCP 8.5, where they rise continually throughout the century. Summer air temp increases 3.7°C (6.66°F). Winter snow water equivalent decreases 2.0 cm (0.8 in).	Much longer growing season Very few if any germinants survive winter Invasives outcompeting Minerals developed nearby Wildfire occurs	Provide water year-round Pull invasives regularly Renew PLO 7312 in 2048 Remove woody debris

4.3 Predicting Future Conditions

In predicting the future condition of the species across the two time frames and three scenarios, we assessed what changes to habitat and demographic factors would occur as a result of predicted changes in the climate, invasions by nonnative invasive plants, mineral development, and wildfire. The following discussion presents analysis of the viability of Fremont County rockcress in the continuation scenario in 2050 and 2100, followed by the best case scenario in 2050 and 2100, and finally the worst case scenario in 2050 and 2100. The implementation of conservation actions has the potential to improve viability, and those are discussed as well, although we do not rely on these hypothetical actions in our evaluation of future condition.

4.3.1 Continuation Scenario

In the continuation scenario for 2050 (see Table 8, 2050), the current trajectory of changing climate and other stressors remains at the current slope. Because temperatures will rise, we anticipate a longer growing season for Fremont County rockcress, though it is likely that fewer germinants will survive winter due to lower precipitation during that crucial period. This would lead to a lower level of recruitment and therefore lower number of non-flowering plants, which would have a negative effect on resiliency. Based on the present capacity of nonnative invasive species to colonize and compete with Fremont County rockcress for available habitat, we anticipate that there will be rare invasions by nonnative invasive species, and these may outcompete some Fremont County rockcress plants for available moisture. However, these nonnative invasive plants may occur at low enough levels that they could be hand-pulled. Minerals would not be developed through 2048 under PLO 7312 (63 FR 9012; February 23, 1998), and there is a possibility that PLO 7312 could be extended for another 50 years. Wildfires would not affect Fremont County rockcress or its habitat due to the lack of fuels around and within Fremont County rockcress habitat. Removing woody debris from dead and down limber pines in the area could serve as a conservation measure to further prevent wildfires from occurring in the area.

In general, the continuation scenario results in decreased abundance of non-flowering plants due to decreases in recruitment and a potential increase in competition with nonnative invasive species in 2050. Assuming that no conservation actions are implemented, the predicted future condition considering a continuation scenario for Occurrence 1 in 2050 is to maintain high levels

of resiliency (see Table 9, Occurrence 1, 2050). This is due to the expected continued high levels of abundance and colonization demographic factors, and the continued high availability of soil, which would not be impacted by changes brought about under this future scenario. Implementation of conservation actions would not alter the projected future condition for the occurrence in the continuation scenario for 2050 because the key factors affecting condition are demographic factors for which we have no potential conservation actions.

In the continuation scenario for 2100 (see Table 8, 2100), we expect to see an even longer growing season than anticipated in 2050 and potentially even fewer germinants would survive winter. A conservation measure to offset this could be to provide water during the winter to increase the potential for survival for germinants, though this is highly unlikely to be realistically implemented. The predictions for nonnative invasives, mineral development, and wildfire remain unchanged from 2050 to 2100, as do the potential conservation actions to limit the effects of these stressors.

The trend of lowered abundance of non-flowing plants, precipitation, and increased competition seen in 2050 would be expected to continue in 2100 under this scenario, and due to competition over time, areas available to Fremont County rockcress plants for colonization decrease as well. Assuming that no conservation actions are implemented, overall, the predicted future condition for Fremont County rockcress Occurrence 1 in the continuation scenario in 2100 is to have moderate levels of resiliency (see Table 9, Occurrence 1, 2100). This is due to decreases in recruitment as evidenced by lower abundance in non-flowering plants, and increases in competition at such a level that areas available for colonization by Fremont County rockcress are instead taken by nonnative invasive species. Implementation of conservation actions would not alter the projected future condition for the occurrence in the continuation scenario for 2100 because the key factors affecting condition are demographic factors for which we have no realistic potential conservation actions.

4.3.2. Best Case Scenario

The best case scenario assumes that global annual GHG emissions (measured in CO_2-equivalents) have peaked or will peak between 2010-2020, with emissions declining substantially thereafter (see Table 7). This correspondingly low increase in summer temperature is not likely to alter the length or intensity of the growing season, and so Fremont County rockcress plants will likely continue to experience a growing season similar to today. Without a change in precipitation, we expect that germinant survival will remain similar to current levels, and therefore abundance of non-flowering plants will stay the same as well. In the best case scenario for both 2050 and 2100, minerals would not be developed within or near Fremont County rockcress habitats, PLO 7312 would be renewed to cover the entire species' range, and competing plants would be kept out of Fremont County rockcress habitat. Finally, wildfires would not be a concern in 2050 or 2100 under the best case scenario, because the rock outcrop habitat of Fremont County rockcress itself is resistant to wildfire.

In summary, under the best case scenario for Occurrence 1 for both 2050 and 2100, we anticipate Fremont County rockcress would have high levels of resiliency (see Table 9, Occurrence 1, 2050 and 2100). This is due to a lack of impacts to the habitat factors of soil, precipitation, and competition, as well as the demographic factors of flowering and non-flowering plant abundance and colonization.

4.3.3. Worst Case Scenario

In the worst case scenario, we expect summer air temperature to increase and that snow water equivalent will decrease. Similar to the continuation scenario, rising temperatures will increase the growing season, but this lengthened growing season may also lead to further drying of the habitat that is exacerbated by lower winter precipitation. These factors would likely lead to lower survival of germinants and fewer individuals being recruited. We expect that cheatgrass and other nonnative invasive species would move into the habitat of Fremont County rockcress and outcompete individual Fremont County rockcress plants for resources and areas to colonize. Because of the longer growing season and enhanced drying of the surrounding area, it is likely that more wildfires would occur in and around Fremont County rockcress suboccurrences and their habitats. Furthermore, under the worst case scenario, the PLO 7312 would expire and mineral development would occur in or around Fremont County rockcress habitats. This could destroy plants directly or remove soil in which they grow. Conservation actions could theoretically be implemented to lessen the effects of these stressors, such as watering the Fremont County rockcress habitat in some critical seasons, pulling nonnative invasive species, removing woody debris that may serve as fuel for wildfires, and renewing PLO 7312 to restrict mineral development away from Fremont County rockcress habitat, but we have no information on whether any of these actions are likely to occur, or whether they could reasonably be carried out.

In summary, the decreased precipitation under the worst case scenario for 2050 would result in decreased recruitment of new plants, as evidenced by lower numbers of non-flowering, vegetative plants. The competition with nonnative invasive species would decrease abundance and colonization of available habitats. Assuming that no conservation actions are implemented, overall, the predicted future condition of Fremont County rockcress Occurrence 1 in 2050 under the worst case scenario is moderate levels of resiliency (see Table 9, Occurrence 1, 2050). This is due to the apomictic reproductive system of the species, which allows even a lower number of plants to continue to reproduce and generate offspring that are both highly adapted to the present environment and able to express phenotypic plasticity in response to changes in the environment.

In the worst case scenario for 2100, we expect that the growing season will expand by weeks if not days, but that, similar to the worst case scenario in 2050, the decreased snow water equivalent and lengthened growing season will enhance drying, which may reduce germinant survival and recruitment. Competition with nonnative invasive plants is expected to be intense under the worst case scenario in 2100, which would lead to declines in abundance and colonization of Fremont County rockcress. More wildfires would be expected to occur in and around Fremont County rockcress habitat, and the presence of dry fuels associated with tree die-offs and nonnative invasive species encroachment in warmer-than-usual temperatures would mean that these wildfires could be devastating to the species if they occurred in and around the species' habitat. Furthermore, under the 2100 worst case scenario, PLO 7312 would expire and not be renewed, and similar to the 2050 worst case scenario, mineral development could destroy plants directly or remove the soil on which they grow. Conservation actions could hypothetically be implemented to lessen the effects of these stressors, such as watering the Fremont County rockcress habitat year-round, pulling nonnative invasive species, removing woody debris that may serve as fuel for wildfires, and renewing PLO 7312 to restrict mineral development away from Fremont County rockcress habitat, but we have no information on

whether these conservation actions could reasonably be implemented or whether any of these conservation actions would in fact occur.

In summary, the warmer temperatures and decreased precipitation under the 2100 worst case scenario would result in decreased survival and recruitment of new plants, leading to a lower abundance of non-flowering plants. Increased competition with nonnative invasive plants would prohibit colonization of Fremont County rockcress into new habitats and decrease the overall abundance of individual plants. Assuming that no conservation actions are implemented, overall, the predicted future condition of Fremont County rockcress Occurrence 1 in 2100 in the worst case scenario is low levels of resiliency. However, if conservation measures were implemented, this could improve resiliency to a moderate level (see Table 9, Occurrence 1, 2100).

Table 9. Prediction of future resilience conditions for each of the demographic and habitat factors for Fremont County rockcress Occurrence 1 in 2050 and 2100, the overall future condition, and the overall future condition with the implementation of conservation actions. Overall condition is determined through averaging all demographic and habitat factors equally. Green = high, yellow = moderate, red = low condition.

Occurrence 1

2050

Scenario	Demographic Factors			Habitat Factors			Overall	Overall
	Flowering plant abundance	Non-flowering plant abundance	Colonization	Soil derived from granite pegmatite	Sufficient precipitation	Freedom from competition	Future condition	Future condition with conservation actions
Continuation								
Best case								
Worst case								

2100

Scenario	Demographic Factors			Habitat Factors			Overall	Overall
	Flowering plant abundance	Non-flowering plant abundance	Colonization	Soil derived from granite pegmatite	Sufficient precipitation	Freedom from competition	Future condition	Future condition with conservation actions
Continuation								
Best case								
Worst case								

Chapter 5. Synthesis and Viability

Regarding resiliency and redundancy, potential stochastic and catastrophic events that may affect Fremont County rockcress in the future are climate change, competition with nonnative invasive species, mineral development, and wildfires. As discussed under *3.2.4 Climate change*, climate models are predicting that precipitation will increase in the winter and spring, decrease in summer, and remain about the same in fall (USGS 2016 p. 3). Snow water equivalent will decline in the winter and spring and soil water storage will decline in the summer and fall (USGS

2016 pp. 4–6). A combination of warmer climate and more precipitation in winter and spring could expand the growing season for this species, particularly because the growing season for this species appears to be limited by the number of frost-free days, and because numbers of individuals appear to be higher in years with higher than average spring precipitation. However, declines in soil water storage in the summer may limit seed production, which could cause declines in recruitment. Furthermore, a decrease in snow water equivalent during winter, when seedlings of Fremont County rockcress are likely to be most vulnerable to desiccation, may lead to lowered survival and recruitment, as evidenced by lower numbers of non-flowering plants. A severe and extended drought, as discussed under **Section 3.2.5 Drought**, could have the potential to eliminate the species by preventing flowering, seed production, germination, or all three of these important functions of population growth. While climate change models are not predicting any extended droughts for the area in which Fremont County rockcress occurs, many global climate models are predicting that droughts, intense precipitation events, and other extreme climate events will occur more frequently worldwide (Dai 2013, p. 52).

Nonnative invasive species are presently not affecting Fremont County rockcress due to the general inhospitable nature of the species' rock outcrop habitat. However, into the future, there is potential for invasives nearby such as cheatgrass to invade the habitat if plant material is allowed to accumulate on the rock outcrop and produce soil. An invasion of cheatgrass or some other nonnative invasive species could potentially occur over a short span of time if the plants outcompete Fremont County rockcress plants for resources such as sunlight, water, and patches of soil to colonize.

The stressor of mineral development has been eliminated from the habitat surrounding Occurrence 1 of Fremont County rockcress through 2048, though the potential for renewal of the PLO 7312 protecting this Fremont County rockcress habitat from development pressure is uncertain. Suitable and potentially occupied habitat outside of Occurrence 1 is not covered by PLO 7312 (see yellow outline in Figure 1), and therefore, it is possible that an unknown occurrence or group of plants could be directly impacted by mineral extraction and loss of suitable habitat. Furthermore, if mining occurred within suitable habitat for the species, it would decrease the potential for new areas to be colonized, and removal of the soil on which the species depends would likely decrease the survival of new recruits. Mineral development, if located at or near the habitat for Fremont County rockcress, has the potential to eliminate an entire occurrence of the species.

Wildfire is not considered a stressor affecting Fremont County rockcress currently. However, as discussed under *3.2.6 Wildfire*, invasions of fire-prone species, increasing droughts resulting from changing climate, and an increasing amount of woody fuel nearby could result in a wildfire affecting the area around Fremont County rockcress habitat. We anticipate that the rocky outcrops on which the species occurs would not be directly involved in a wildfire and would likely serve as a fire break, though it is possible that individual Fremont County rockcress near or touching other plants or plant material could be lost. Conversely, a wildfire may also serve to improve available habitat for Fremont County rockcress by removing competing plants and exposing currently covered rock outcrop habitats, thus creating new habitats available for colonization by Fremont County rockcress. However, a very intense, catastrophic fire could have the potential to destroy an entire occurrence of Fremont County rockcress. Additionally, because the suboccurrences are so near each other (1,100 m (3,600 ft) apart), it is possible that the same fire could remove all suboccurrences from the landscape, which would eliminate the

known range of the species entirely. Because the species is represented by a single known occurrence composed of eight suboccurrences approximately 1,100 m (3,600 ft) apart, there is some level of protection against a localized catastrophic event. However, if an event or series of events occurred that was far-ranging and catastrophic, it could lead to the elimination of the species.

In terms of representation, due to our lack of information on population genetics, we evaluated the species based on the breadth of diversity within the species. These include three ecological settings of granite outcrop, gravel pavement, and margins of granite outcrop and gravel pavement; two morphological variants of flowering and nonflowering plants; four phenological stages of typical, early, late, or aborted reproduction; and a single large occurrence composed of eight suboccurrences. Since the species is a narrow endemic plant occurring in over a small area, these are not wide variations, but even this small amount of diversity may provide some level of representation, and individual plants are themselves adaptable to changing conditions. It is unlikely that changes in future circumstances will affect the levels of ecological, morphological, phenological, and occurrence diversity that contribute to representation, though it is possible that more individuals within an occurrence could express certain traits given environmental pressures or in response to stressors. Nevertheless, because there are not high levels of diversity within the species, we consider representation to be low.

In **Chapter 3**, we assessed the current condition of Fremont County rockcress by reviewing the current status of the 3Rs in terms of individual and population-level resilience, redundancy in response to catastrophic events, and representation as indicated by diversity in ecological, morphological, and phenological characteristics, and the presence of a single occurrence. Our results indicate that the current condition of Fremont County rockcress is characterized by having a single, highly resilient occurrence, moderate redundancy, and low representation, all of which is in part due to its apomictic reproductive system, which allows individual plants to contribute towards resiliency and redundancy. In **Chapter 4**, we evaluated the potential future condition of Fremont County rockcress by predicting the species' response to a range of scenarios involving changes in climate, competition with nonnative invasive species, mineral development, and wildfires, which were deemed the most likely stressors to affect Fremont County rockcress into the future. We determined that the future condition of Fremont County rockcress could range from the same levels of the 3Rs as the species currently has under the best case scenario to low levels of the 3Rs under the worst case scenario, assuming no conservation actions are implemented. This is driven by the resiliency of Occurrence 1, the apomictic reproductive system of the species and its ability to reproduce individually, and the lack of stressors impacting the species at a high level.

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Appendix. Glossary of terms

Agamospecies: A group of obviously related asexually reproducing individuals regarded as a group equivalent to a species. An **apomict** population the members of which, for morphological, cellular, or other reasons, are considered as having a common origin. Synonymous with **microspecies**.

Agamospermy: Asexual reproduction in which seeds are produced from unfertilized ovules. **Parthenogenetic** reproduction in which sexual union is incomplete because of abnormal development of the pollen and embryo sac.

Apomeiosis: Literally, "without **meiosis**," and technically without meiosis I. Imperfect or suppressed **meiosis** in which the first phase of **meiosis** fails due to chromosome pairing abnormalities, Meiosis II (basically mitotic cell division) occurs normally. The result of apomeiosis is an embryo with the same number of chromosomes as the mother plant.

Apomict: One produced or reproducing by **apomixis**.

Apomictic: Adjective of **apomict**.

Apomixis: **Parthenogenetic** development of sex cells without fertilization. Reproduction involving specialized generative tissue but not dependent on fertilization. Asexual formation of seed from maternal tissue, avoiding process of meiosis and fertilization, leading to embryo development.

Diplosporic: Condition of reproduction with two unreduced **megaspores** where one degenerates while the other makes an unreduced **gametophyte** with an unreduced egg cell. A form of **apomixis** in which the embryo forms directly from the **megaspore** mother cell.

Gametophyte: The gamete-producing, usually haploid generation in the life cycle of a plant, which arises from haploid spores produced as a result of **meiosis** by the multi-ploid generation or mother plant. In flowering plants, the male gametophyte is represented by the pollen tube and its nuclei while the female gametophyte is represented by the embryo sac.

Megaspore: Typically, the haploid spore formed after **meiosis**. In **diplosporic apomictic** species, it is the unreduced cell that gives rise to the embryo.

Meiosis: A specialized type of cell division that reduces the chromosome number by half. Typical in sexually reproducing single- and multi-cellular organisms. Meiosis occurs in two stages, the first of which (meiosis I or the reduction division) separates chromosome pairs to reduce the number per cell by half (from $2n = 14$ to $n = 7$ in *Boechera*) while the second (meiosis II or the equational division) separates the chromatids as in mitosis.

Microspecies: A genotype that is perpetuated by **apomixis**. A small, local race with limited genetic variability that is clearly differentiated from related forms.

Parthenogenetic: Reproduction by development of an unfertilized, usually female, gamete. Referring to a special type of reproduction in which an egg develops without entrance of a sperm.

Phenotypic plasticity: The capacity of a single genotype to exhibit variable phenotypes in different environments. The ability of a species to change its phenotype in response to environmental conditions. Can alter appearance, physiology, and development in response to changes in the environment.

Redundancy: The ability of a species to withstand catastrophic events. Redundancy protects species against the unpredictable and highly consequential events for which adaptation is unlikely. In short, it is about spreading the risk. In general, redundancy is best achieved by having multiple populations widely distributed across the species' range. Having multiple populations reduces the likelihood that all populations would be affected simultaneously, while having widely distributed populations reduces the likelihood of populations possessing similar vulnerabilities to a catastrophic event.

Representation: The ability of a species to adapt to near and long-term changes in the environment; it's the evolutionary capacity or flexibility of a species. Representation is the range of variation found in a species, and this variation--called adaptive diversity--is the source of species' adaptive capabilities. Representation can, therefore, be measured through the breadth of adaptive diversity of the species. The greater the adaptive diversity, the more responsive and adaptable the species will be over time, and thus, the more viable the species is. Maintaining adaptive diversity is achieved by conserving both the ecological diversity and genetic diversity of a species.

Resiliency: The ability to sustain populations in the face of environmental variation and stochastic events. Environmental variation includes normal year-to-year variation in rainfall and temperatures, as well as unseasonal weather events. Stochastic events include fire, flooding, and storms. Simply stated, resiliency is having the means to recover from "bad years" and disturbances. To be resilient, a species must have healthy populations; that is, populations that are able to sustain themselves through good and bad years. The healthier the populations and the greater number of healthy populations, the more resiliency a species possesses.

Triploid: Having three copies of each chromosome, which occurs through hybridization and **apomictic** reproduction.

Unreduced: Not reduced. Applied to gametes or gametophytes in which the chromosome number has not been reduced by meiosis and thus equals the number observed in the maternal sporophyte.